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DEPARTMENT OF DEFENSE
HANDBOOK

WATER SUPPLY SYSTEMS

THIS HANDBOOK IS FOR GUIDANCE ONLY. DO NOT CITE THIS DOCUMENT AS A REQUIREMENT.

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ABSTRACT

This handbook provides design guidance for use by qualified engineers in designing water supply systems. The handbook includes criteria for determining quantity and quality requirements; selecting source of supply, pumps, and treatment processes and facilities; and for designing distribution and transmission systems, storage facilities, and buildings.

FOREWORD

This handbook has been developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Military, other Government agencies, and the private sector. This handbook was prepared using, to the maximum extent feasible, national professional society, association, and institute standards. Deviations from this criteria, in the planning, engineering, design, and construction of Military facilities, cannot be made without prior approval of NAVFACENGCOMHQ Criteria Office Code15, or HQ AF/ILEV, whichever is appropriate.

Design cannot remain static any more than can the functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged and should be furnished to Commander, Naval Facilities Engineering Command, Criteria Office. 150 Gilbert Street, Norfolk, Virginia, 23511-2699.

THIS HANDBOOK SHALL NOT BE USED AS A REFERENCE DOCUMENT FOR PROCUREMENT OF FACILITIES CONSTRUCTION. IT IS TO BE USED IN THE PURCHASE OF FACILITIES ENGINEERING STUDIES AND DESIGN (FINAL PLANS, SPECIFICATIONS, AND COST ESTIMATES). DO NOT REFERENCE IT IN MILITARY OR FEDERAL SPECIFICATIONS OR OTHER PROCUREMENT DOCUMENTS.

CIVIL ENGINEERING CRITERIA MANUALS

Criteria Manual/Handbook	Title	PA
DM-5.4	Civil Engineering Pavements	PACDIV
MIL-HDBK-1005/6	Trackage	NORTHDIV
MIL-HDBK-1005/7A	Water Supply Systems	NAVFAC Criteria Office
MIL-HDBK-1005/9A	Industrial and Oily Wastewater Control	NAVFAC Criteria Office
DM-5.10	Solid Waste Disposal	PACDIV
MIL-HDBK-1005/13	Hazardous Waste Storage	NAVFAC Criteria Office
MIL-HDBK-1005/16	Wastewater Treatment System Design Augmenting Handbook	NAVFAC Criteria Office

NOTE: Design manuals, when revised, will be converted to military handbooks. Inactive criteria have not been listed.

WATER SUPPLY SYSTEMS

CONTENTS

Page

FIGURES

TABLES

Section 1: INTRODUCTION

1.1 Scope. This manual presents requirements for the design of water supply systems for Military activities.

1.2 Cancellation. This handbook, MIL-HDBK-1005/7A, Water Supply Systems, cancels and supersedes MIL-HDBK-1005/7, Water Supply Systems, dated 30 November 1988 and AFM 88-10, Water Supply, Volumes 1-5.

1.3 Source of Supply. The capacity of potable supplies should be developed whenever possible, to obviate any need for a nonpotable supply (except for waterfront facilities, refer to MIL-HDBK-1025 Series, Piers and Dockside Facilities, and MIL-HDBK-1029 Series, Drydocks and Marine Railways).

1.3.1 Potable Water Sources. The potable water supply should be obtained from a nearby public system. If this is not feasible, sources should be developed especially for the Military activity. Brackish or salt water should be used only when other sources are unavailable, and should be converted to fresh water by a suitable process.

1.3.2 Nonpotable Water Sources. Separate nonpotable water supplies should be considered for active waterfront facilities. At active and repair berths and drydocks, cooling, flushing and fire protection requirements may be met using nonpotable fresh or salt water supplies. Only one nonpotable system should be provided, and it should meet the requirements of MIL-HDBK-1025 Series. At inactive berths, salt or nonpotable water should be used, when available, for fire protection; if not available, potable water may be used. Nonpotable water supplies should be designed to preclude any possible contamination of potable water supply sources or systems.

1.4 Quantity Required. Water supply plans should provide for quantities sufficient to fulfill the Military activity's current demands, and all reasonable future or prospective demands.

1.5 Quality. The following criteria apply for the quality of water.

1.5.1 Potable Water Quality. Except when otherwise permitted by the Bureau of Medicine and Surgery (BUMED), the U.S. Environmental Protection Agency (EPA) Safe Drinking Water Act primary and secondary drinking water regulations, as published in the 40 Code of Federal Regulations (CFR), Part 141 through 143 and all State and local water quality standards must be met in full by providing necessary treatment. Any additional specific standard set by BUMED must be observed where applicable. Refer to NAVMED P-5010-6, Manual of Naval Preventive Medicine, Chapter 6, "Water Supply Afloat," for shore side potable water requirements for ships. Overseas locations may be affected by Final Governing Standards (FGS) and Overseas Environmental Baseline Guidance Documents (OEBGD).

1.5.2 Nonpotable Water. Segregate potable and nonpotable systems so that nonpotable water cannot be injurious to health or cause other hazards.

1.6 Cost Policy. Designs should be the most economical obtainable, consistent with the Military activity's requirements. For cost analysis, balance the annual operating cost against annual fixed charges for different sources of supply and different designs. The life of the system should cover the expected need for the Military activity. Fixed annual charges include insurance and either interest and depreciation or amortization. Annual operating cost include treatment chemicals, energy consumption, operating labor, maintenance, and replacements, where appropriate.

1.7 Design Policy. To give absolute assurance of a continuously safe water supply, design the system in accordance with approved engineering practice.

1.8 Hazard of War Damage. Observe all necessary precautions against sabotage and interruptions as a result of war damage. Refer to OPNAVINST 5510.45, U.S. Navy Physical Security Manual. For Air Force projects refer to AFMAN 32-1071, Security Engineering Manual.

1.8.1 Planning for Non-war Emergencies. Refer to AWWA M19, Emergency Planning for Water Utility Management, for non-war emergencies such as earthquakes, hurricanes, tornadoes, floods, and vandalism.

1.9 Initial Design Investigation. Develop quantity and quality requirements as the first step in design. Surveys by a competent agency are required to obtain the following data on supply source:

a) Hydrological data

b) Geological data

c) Quality of raw water

d) Sources of pollution

e) Conflicting uses

f) Water rights

g) Land ownership and rights-of-way, for offsite sources. For additional required design data, see Table 1.

Table 1
Information Required for Design of Water Supply System

ITEM		REQUIREMENTS
Topographic map		For layout of system, use USGS maps for preliminary investigations. For final design, use specially prepared maps. Soil maps and subsurface data prepared from boring logs made by a competent agency, for structural design.
Soil conditions		Soil maps and subsurface data prepared from boring logs made by a competent agency, for structural design.
Transportation		Facilities available for system construction and operation.
Power supply		Available normal and emergency power from local utility or Military’s own power plant.
Local utility maps		Maps of water, sewer, drain, gas, electrical lines, etc., for designing the transmission and distribution systems. Obtain detailed information from local utility companies and surveys.
Suitability and availability of local material		For construction, operation, and maintenance. Important when the site is remote or inaccessible.
Climate Conditions		Allow for the design & operational impact in very cold or hot climates.
Environmental Studies & Reports		For establishing site contamination and other potential environmental problems. Establish need for formal Environmental Impact submissions.
Local code and trade union rules		Affects design and construction.

Section 2: QUANTITY REQUIREMENTS

2.1. Factors Affecting Use. Consider the following factors affecting use ashore:

a) Water uses (domestic, industrial, fire protection)

b) Peak demands (all uses)

c) Other essential demands

d) Missions of the activity

e) Climatic effects

f) Permanency of installation (permanent and temporary field bases).

g) Overseas Final Governing Standards (FGS)

2.2 Specific Requirements. Total requirements are related to domestic, industrial, and fire protection requirements. Specific requirements for use ashore are discussed below.

2.2.1 Domestic Uses. Domestic uses include drinking water, household uses, and household lawn irrigation.

2.2.1.1 Per Capita Requirements. Use data in Table 2 for permanent and temporary installation.

Table 2
Average Potable Domestic Water Requirements
Gallons Per Capita Per Day (gpcd)

USE CATEGORY	TROPIC	TEMPERATE
Unaccompanied Personnel Housing	155	135
Family Housing	180	135
Workers (per shift)	45	45

2.2.1.2 Controlling Demands. All demands will be multiples of the average demand, expressed as gallons per minute (gpm) or gallons per day (gpd). The average demand, in gpd, should be calculated by Equation (1):

EQUATION (1): Avg demand in gpd = gpcd x design population x growth factor

Use the following growth factors in equation (1):

a) Large systems (5,000 population or greater), 1.25.
b) Small systems (populations less than 5,000), 1.50.

This equation must be performed for each use category shown in Table 2, and the results must then be added together to determine total average demand.

Other controlling demands should be evaluated by Equation (2): Demand = avg demand in gpd x K

using the following data for the coefficient, K:

DEMAND	UNITS OF DEMAND	COEFFICIENT K	
		POPULATION <5000	POPULATION >5000
Maximum Day Flow	Gpd	2.25	2
Maximum Hour Flow	Gph	4.0/1,440	3.5/1,440
Instantaneous Peak Flow	Gpm	5.0/1,440	4.5/1,440

The designer may make allowances, as deemed necessary, for small activities where all or nearly all demand occurs during working hours.

If a planned buildup or population decrease can be foreseen, this change should be taken into account.

2.2.2 Industrial Uses. These uses include cooling, issues to ships, irrigation, swimming pools, shops, laundries, dining, processing, flushing, air conditioning, and boiler makeup. As a guide to planning, refer to water demand data at other activities having uses similar to those anticipated. For specific requirements, refer to Table 3.

2.2.3 Fire Protection Demands. Refer to MIL-HDBK-1008C, Fire Protection for Facilities Engineering, Design, and Construction, for criteria.

2.3 Design Capacity of System Components. In planning, each system should be analyzed to determine the governing water use. The coincident demand of various uses will determine the design capacities of components of the system.

2.3.1 Source of Supply. The source should meet the Military activity's quantity demands. Where there is inadequate storage between the source and the treatment plant or distribution system, the supply should provide maximum day domestic demand expressed by Equation (2), plus industrial use demand. If wells are the source of supply, sufficient capacity should be available to satisfy the maximum day domestic demand plus industrial use demand, with the largest well (or mechanical system) out of service.

Table 3
Industrial Water Requirements
Potable Water - Permanent Installations

USE	UNIT	REQUIREMENTS		
		MIN	AVG	MAX
Air conditioning:	gpm/ton	–	0.05	0.10
Cooling - diesel engines:	gpm/bhp	–	0.01	0.02
Cooling - steam power	gal/kwh	0.80	1.30	1.70
Issue to ships - (domestic uses): single berth more than single berth	 gpm gpm		 1,000 [2] 1,000 [2]	 – 2,000 [3]
Laundries	gal/lb	3	–	6
Irrigation small lots large areas	 gpd/100 ft À2Ù gpad	 16 7,000	 – –	 32 14,000
Motor vehicles	Gpd/car	30	–	50
Restaurants	Gal/ Meal	0.5	–	4.0

[1] Use as a guide only.
[2] Up to 2,000 linear ft of berthing length.
[3] 500 gpm for each additional 2,000 linear ft of berthing length, but not exceeding 2,000 gpm.

2.3.2 Treatment Plant. The design capacity of treatment plants should be able to meet maximum day domestic demand expressed by Equation (2), plus industrial use demand, assuming adequate equalizing storage following treatment. Without equalizing storage, the plant must be able to meet maximum hour (h) flow expressed by Equation (2), plus industrial use demand.

2.3.3 Transmission Mains. Where the distribution is pumped from storage, transmission mains should have capacities equal to the maximum-day demand as expressed by Equation (2), plus industrial use demand. Without such storage, they should meet maximum hour demands.

2.3.4 Distribution System. The minimum capacity of a distribution system should be sufficient to meet these conditions:

a) Instantaneous peak domestic and industrial flows combined

b) Maximum fire demands, plus 50 percent of average domestic demands, plus industrial demands which cannot be restricted during the fire

c) Replenishment of normal storage volume within 24 hours of average demand after a fire.

2.3.5 Reservoirs. Reservoir capacity should be adequate to satisfy the total of the following requirements:

a) Peak fire flow demand as given in MIL-HDBK-1008C.

b) 50 percent of average daily consumption (domestic and industrial).

c) Minimum working volume of one hour at average demand (domestic and industrial) for scheduling of treatment plant equipment and service pumps maintenance.

2.4 Specific Requirements for Waterfronts and Drydocks. For waterfront requirements, refer to MIL-HDBK-1025 Series. For drydock requirements, refer to MIL-HDBK-1029 Series, Drydocks and Marine Railways.

Section 3: QUALITY REQUIREMENTS

3.1 Water Examination

3.1.1 Qualities To Be Examined. Water for Military activities should be examined for the following characteristics (as appropriate):

a) Bacteriological quality

b) Physical characteristics

c) Chemical characteristics

d) Biological quality

e) Radiological quality.

3.1.2 Sampling Points. For the locations of water sampling points and the reasons for sampling at each point, refer to Table 4. Facilities should be included for sampling at each location.

Table 4
Water Sampling Points

LOCATIONS	REASONS FOR SAMPLING
Source of supply	To evaluate and classify raw water quality To detect and assess the degree of pollution To assess the treatment required for beneficial uses
Treatment plant	To ascertain the efficiency of the treatment processes To control quality as delivered to the distribution system
Transmission and distribution systems	To locate the cause of any sudden deterioration in quality within the system To control scale and corrosion or slime in the systems
Point of use	To ascertain the quality for potability, palatability, and other beneficial uses

3.1.3 Methods. Methods published in American Public Health Association (APHA), Standard Methods for Examination of Water and Wastewater, or as specified by EPA or the State, should be used in the examination of water.

3.1.4 Frequency of Examination. An initial investigation of a new source of supply is required. At least one complete bacteriological, physical, and chemical examination of raw water is required. When there are sufficient data from existing records, or from hydrological, geological, and sanitary surveys, to establish that the sample is representative, no additional tests are necessary.

3.1.4.1 Supplementary Investigations. Requirements for the frequency of sampling are contained in the 40 Code of Federal Regulation (CFR) Part 141, U.S. EPA National Primary Drinking Water Regulations. Designs should include permanent sampling points if subsequent sampling is required.

3.2 Quality Criteria. Water for domestic uses should meet the requirements of the 40 Code of Federal Regulation (CFR) Part 141, U.S. EPA National Primary Drinking Water Regulations and Part 143, National Secondary Drinking Water Regulations, as may be modified by BUMED (refer to par. 1.5.1), or by State standards. Individual State standards may be more stringent than national requirements. The facility may be required to meet requirements of that individual state as well as the national requirements and the BUMED.

3.2.1 Specific Criteria. The criteria for uses and protection are as follows:

3.2.1.1 Domestic Uses. Ordinary requirements are stated in 40 Code of Federal Regulation (CFR) Part 141.

3.2.1.2 Industrial Uses. Requirements for boiler feed water are listed in MIL-HDBK-1003 Series, Mechanical Engineering. Other industrial requirements are outlined in American Water Works Association (AWWA), Water Quality and Treatment, a Handbook of Public Water Supplies.

3.2.1.3 Fire Protection and Flushing Uses. In nonpotable water, the following substances should generally be removed or reduced to harmless concentrations:

a) Oil or grease, because of fire hazard

b) Substances which accelerate corrosion and tuberculation.

c) Debris, silts, and other suspended solids

d) Organic matters which generate odors and corrosive hydrogen sulfide gas in storage reservoirs

e) Algae, fungi, worms, barnacles, and other slime-forming pollutants which can clog pipes or nozzles.

An economic study may be necessary relative to b) and d) above to determine if it is less expensive to remove these constituents or to make the system corrosion resistant.

3.2.1.4 Sanitary Protection. Avoid all connections to non-potable systems where possible. Refer to AWWA Manual M14, Recommended Practice for Backflow Prevention and Cross-connection Control for recommended practices and the Uniform Plumbing Code. Supplemental information is provided by AF 132-1066, Plumbing Systems.

Section 4: SOURCE OF SUPPLY

4.1 Selection of Water Source

4.1.1 Investigations. For permanent and temporary installations, investigate all reasonably promising sources. For field bases, carry out reconnaissance studies to locate sources with adequate supply and quality.

4.1.2 Types of Sources. Select supplies from the following sources which may meet requirements, in the order of preference listed:

a) Municipal supplies

b) Groundwater (wells, infiltration galleries, and springs)

c) Surface water (natural flows, natural storage, impounded storage, and rainwater catchments)

d) Nonpotable sources (groundwater with high salinity, surface water with high salinity, and sea water)

e) Hauled supplies.

4.1.3 Factors Affecting Selection. Determine availability of supply by whether sources exist and are not already fully used.

4.1.3.1 Adequacy of Yield. Compare the yield with the needs of the activity.

4.1.3.2 Suitability for Use. Water should be of a quality that does not require excessive and costly treatments to render it usable. Use Table 5 as a guide to classify raw water sources for domestic use.

4.1.3.3 Conflicting Uses. Interference with other uses of the same source of supply should be investigated and avoided. Possible conflicting uses include:

a) Conservation requirements

b) Pollution control requirements

c) Prior water rights.

4.1.3.4 Water Rights. Legal advice should be obtained concerning the title of the water at the source of supply. Refer to Water Rights in the Fifty States and Territories by Kenneth Wright, latest edition.

4.1.3.5 Economics of Water Development. Analysis of development economics should follow Military policy.

4.2 Municipal Supplies

4.2.1 Quality Examination. Examination of the water is not required if it is reported to be satisfactory by a competent agency. Unless reported as satisfactory by a competent U.S. agency, all foreign public water should be considered as of doubtful quality. Examinations are mandatory. Treatment is required unless consistent high quality is absolutely certain. Check OEBGD and appropriate FGS.

4.2.2 Rights and Responsibilities. Liaison with municipal waterworks officials should be established by the military, and a determination made of the adequacy of the municipal source to meet the quantity, quality, and pressure of water required by the military. The location and method of connection to the municipal source must be acceptable to the supplier. Where the quality of the municipal water supply does not meet the standards of 40 Code of Federal Regulation (CFR) Part 141, treatment by the military must be provided.

4.2.3 Information Required. Information on the municipal system will be obtained from the public water supply agency. Where no reliable records are available, conduct special surveys to obtain the information and data listed in Table 6.

Table 5
Classification of Raw Water Sources for Domestic Uses

Quality Criteria	Suitability as Source of Supply		
	Good	Fair	Poor
Physical			
Color (Units)	0-15	15-50	Over 50
Odor (Threshold Odor Number)	0-3	3-10	Over 10
Temperature (Degrees Fahrenheit)	35-50	50-80	Over 80
Turbidity (Units)	0-25	25-250	Over 250
Chemical (1)			
Alkalinity ($CaCO_3$)	25-150	150-400	Over 400
Alkyl Benzene Sulfonate (ABS)	0	0-0.5	Over 0.5
Ammonia (NH_3)	0-0.1	0.1-1.0	Over 1.0
Arsenic (As)	0	0-0.01	Over 0.01
Barium (Ba)	0	0-0.1	Over 0.1
BOD	0-1.5	1.5-4.0	Over 4.0
Cadmium (Cd)	0	0-0.01	Over 0.01
Carbon Chloroform Extract (CCE)	0-0.1	0.1-0.2	Over 0.2
Carbon Dioxide (CO_2)	0-10	10-50	Over 50
Chloride (Cl)	0-50	50-250	Over 250
Chromium (Cr) - Hexavalent	0	0-0.01	Over 0.01
Copper (Cu)	0-0.5	0.5-1.0	Over 1.0
Cyanide (CN)	0	0-0.1	Over 0.1
Fluoride (F)	0.8-1.3	1.3-2.0	Over 2.0

Table 5 (Continued)
Classification of Raw Water Sources for Domestic Uses

Hydrogen Ion (pH)	6.5-8.5	6.0-9.0	<6.0 >9.0
Iron (Fe)	0-0.3	0.3-1.0	Over 1.0
Lead (Pb)	0	0-0.01	Over 0.01
Manganese (Mn)	0-0.05	0.05-0.5	Over 0.5
Nitrates (NO_3)	0-10	10-25	Over 25
Nitrites (NO_2)	0-1.0	1.0-5.0	Over 5.0
Phenols	0	0-0.0001	Over 0.0001
Phosphates (PO_4)	0-10	10-50	Over 50
Selenium (Se)	0	0-0.01	Over 0.01
Silver (Ag)	0	0-0.02	Over 0.02
Sulfate (SO_4)	0-125	125-250	Over 250
Total Dissolved Solids (TDS)	100-300	300-600	Over 600
Total Hardness ($CaCO_3$)	50-150	150-500	Over 500
Zinc (Zn)	0-1.0	1.0-5.0	Over 5.0
Hydrogen Sulfide (H_2S)	0-0.2	0.2-5.0	Over 5.0
Biological			
Coliforms, MPN per 100 ml	0-100	100-5,000	Over 5,000
(Monthly Average)	Less than 5 percent of samples over 100	Less than 20 percent of samples over 5,000	

(1) With the exception of pH, all values are in terms of ppm.

Table 6
Information Required on Municipal Water Supplies

ITEM	DETAILED DATA REQUIRED
Quantity of supply	Type of water source(s). Safe yield (mgd). Population (present and projected future). Per capita consumption (gpcd). Fire demands. Industrial uses and demands. Other commitments and prior water rights.
Quality of supply	Type and capacity of municipal treatment plant(s). Summarized operating records of treatment plants(s). Water quality analysis.
Transmission lines and distribution system	System layout. Sizes and conditions of pipe lines. Pressures available in the system. System storage, size and location.
Local codes and regulations	Special regulations of local regulatory agencies.

4.2.4 Connecting Structures. Types and construction of connecting structures should be selected to meet local requirements insofar as they do not conflict with Military criteria.

4.2.4.1 Interconnections

a) Direct Connection to Pipeline. Use tapping sleeve valves when the flow cannot be interrupted during construction. Otherwise, cut in a tee. Include a valve and, where required, a reduced pressure backflow preventer between the municipal system and the Military system.

b) Intake from Reservoir. Use existing intakes where feasible.

4.2.4.2 Appurtenances

a) Meters. Locate meters away from normal traffic but accessible, and protect them against unauthorized intrusion. Meter types are as follows:

(1) propeller type

(2) Venturi tube

(3) ultrasonic flowmeter

(4) Dall meter.

b) Backflow Preventers. Provide these safeguards at all points where a nonpotable water system must be connected to a potable system. Refer to AWWA M14, Recommended Practice for Backflow Prevention and Cross-Connection Control, local plumbing code, and AF 132-1066 for Air Force projects.

c) Review manufacturer's literature to insure proper installation conditions.

4.3 Groundwater. Refer to AWWA Manual M21, Groundwater, and Groundwater and Wells by Fletcher G. Driscoll, Johnson Division, St. Paul Minnesota for detailed information relating to types of groundwater wells, quantitative evaluation of groundwater wells, groundwater quality and contamination.

4.4 Groundwater Collection Works

4.4.1 Wells. Selection of the type of well is to be guided by AWWA Manual M21 and AWWA Standard A100, Water Wells, or FGS.

4.4.1.1 Test Well Pumping. After investigation has indicated the best location for groundwater development, a test well is generally used to determine well capacity and appropriate well spacing. A test well may be a small diameter temporary installation in a test hole or, if preliminary data is very promising, it may be a permanent installation. Pumping tests require one pumped well and one or more observation wells. For a permanent installation, at least one observation well should be 10 to 15 ft from the pumped well, with others 50 ft or more away. The pumped well should be either in the best test hole or not more than 10 ft from it.

a) Duration of Test. The test should run a minimum of 24 hours after development of well, or as long as required by any applicable regulations. Longer tests, up to several weeks duration, may be desirable to verify adequacy of the information.

b) Records Required. Secure the following data:

(1) Initial static water level in each well

(2) Pumping rates; at least every hour. Pumping should be maintained at a constant rate.

(3) Drawdown data. Measure water levels in pumping well and also in all observation wells.

(4) Rate of recovery

(5) Where the formation's capability is doubtful, register water levels at each observation well with an automatic recorder accurate to 0.02 feet.

(6) Water samples and analyses. For a major new development, or one of uncertain mineral quality, at least five samples should be taken at periods approximating 0.01, 0.05, 0.10, 0.5 times the test duration, and at the end of the test.

c) Analysis of Tests. Where the formation capacity is in question, use Theis’ non-equilibrium formula. Refer to

Groundwater and Wells, by Driscoll, and AWWA Manual M21 for a description of the formula.

4.4.1.2 Characteristics

a) Number. Provide at least two wells, if possible.

b) Yield. After making allowance for standby wells and reserve for future needs, the total yield should be no less than the maximum daily consumption at the Military activity.

c) Diameter. Determine the size of each well using the total yield required, the number of wells to be constructed, and the capacity of wells at different diameters. The dimensions may be governed by the construction facilities available. Use the following as a preliminary guide for sizing the diameter of deep-drilled wells according to the anticipated yield.

ANTICIPATED CAPACITY (gpm)	CASING DIAMETER (in.)
50	6
50-300	8
300-500	10
500-750	12
750-1,000	16
1,000-2,000	20
2,000-3,000	24
Over 3,000	30

d) Depth. Drill wells deep enough to:

(1) Penetrate an adequate depth into the water-bearing aquifer.

(2) Allow for installation of an adequate length of screen (refer to requirements in par. 4.4.1.3, Well Construction).

(3) Allow for installation of pumping equipment below depth of maximum drawdown.

e) Specific Capacity. This factor equals the yield divided by the drawdown, as determined by the pumping test. It is to be used as a measure of well capability for determining the pumping lifts required at different pumping rates (expressed as gallons per minute per foot (gpm/ft) of drawdown).

f) Spacing of Wells in the Field. Use test pumping data to determine minimum well spacing. Use the data collected from the pumping test to evaluate the effects of interference between wells. The drawdown at any point in the area of influence, caused by the discharge of several wells, equals the sum of the drawdowns (at that point), caused by the wells individually (unless the formation has severe limiting boundaries). Determine the final spacing of wells from investigation of the following factors:

(1) Operation estimated to be successful during the life of the facility.

(2) Extra pumping life required for closely spaced wells and increased pumping costs.

(3) Extra piping and power transmission lines required for widely spaced wells and resulting costs.

4.4.1.3 Well Construction. Refer to Groundwater and Wells by Driscoll for detailed construction methods.

4.4.1.4 Well Development. After completion, each well should be developed to full capacity. The most commonly used methods are pumping and surging; with surging being the preferred method if sand is present or well capacity is low.

a) Methods Available

(1) Pump Surging. This method involves repeated cyclical pumping from a lower to a higher rate, until the capacity of the well is reached.

(2) Surge Block. In this method, surging is created by the rapid up-and-down motion of a plunger. Hexametaphosphates may be added to the well water to free clays or other fines. Surging should be continued until all sand and mud are removed from the well.

(3) Injection of Compressed Air. The injection of compressed air at 100 to 150 psi is repeated until the sand accretion becomes negligible.

(4) Back washing. This method involves filling the well with water and forcing it out repeatedly by air pressure until the well is developed.

(5) Solid Carbon Dioxide. In this method, inhibited hydrochloric acid may be poured into the well first. Compressed air is then applied to force the acid into clay-clogged strata. Finally, solid carbon dioxide (dry ice) blocks are dropped into the well. The surge produced by the gas effects the release of the clays in the strata.

b) Results Required. At the conclusion of the development, suspended matter should not exceed 2 ppm in water delivered, as determined by various samples. The point of collection is important as the samples must be representative.

4.4.1.5 Sanitary Protection. Protect all wells against surface and subsurface contamination in accordance with EPA-570/9-75-001, Manual of Individual Water Supply Systems. In particular, extend the well casing a minimum of 12 in. above grade and seal the well top against surface contamination.

a) Disinfection of Well. Follow standards for AWWA, A-100.

b) Sealing Abandoned Wells. Follow standards for AWWA, A-100.

4.4.1.6 Saltwater Intrusion Protection. In a coastal aquifer, avoid over pumping which induces salt water into a fresh groundwater basin. In certain situations, seawater intrusion barriers may be necessary.

a) Control Methods. Control of saltwater intrusion may be accomplished by:

(1) Modification of pumping

(2) Artificial recharge

(3) Pumping troughs

(4) Pressure ridges

(5) Subsurface barriers

b) Applications and Limitations of Control Methods.

(1) Modification of Pumping. Seek to reduce the pumping draft or to rearrange the pumping pattern by moving the wells inland toward the inflow portion of the groundwater basin. This is usually the most economical method, although it does not fully utilize the groundwater storage capacity.

(2) Artificial Recharge. An intruded aquifer may be artificially recharged from spreading areas or recharge wells with imported high quality supplemental water, with trapped surface runoff, or with treated wastewater.

(3) Pumping Trough. This method consists of forming a trough below the groundwater level, by pumping a mixture of fresh and salt water to waste from a line of wells adjacent to and paralleling the source of salt water. It reduces the usable storage capacity of the basin, wastes fresh water, and is costly to install and operate; but it is sometimes used as an expedient until other methods can be installed, or in conjunction with a pressure ridge.

(4) Pressure Ridge. Control is obtained by forming and maintaining a fresh water pressure ridge adjacent to and paralleling the coast. Although it does not reduce the usable groundwater storage capacity, it requires supplemental water of high quality and has high initial and operating costs.

(5) Subsurface Barrier. Such a barrier is feasible when located in a narrow, shallow alluvial canyon connecting inland to a large aquifer. This method maintains the storage capacity of the basin, but has a high initial cost.

4.4.2 Springs. Many springs fluctuate in their yield and are subject to possible pollution. Frequently, spring water is of less desirable sanitary quality than other underground sources.

4.4.2.1 Types. Springs may be characterized and classified as thermal ,gravitational, depression, contact, artesian, and tubular or fracture. Thermal springs are not used since their waters are likely to be highly mineralized. Select from other types with due consideration of yield, quality, and other factors.

4.4.2.2 Collection Works. Select suitable types of collection works as follows:

a) Collection chamber, for all gravitational springs

b) Open trenches, for depression and contact springs

c) Buried pipes, for depression and contact springs

d) Wells, for artesian springs

4.4.2.3 Sanitary Protection. Provide protection against pollution of spring water in accordance with EPA-570/9-75-001.

4.4.3 Infiltration Galleries. For collateral readings, refer to Infiltration Galleries in Water and Wastewater Engineering, by Fair, Geyer, and Okun. These collectors, generally placed horizontally at right angles to the direction of flow, are served by gravity flow. Consider the applications and limitations of the following types.

4.4.3.1 Open Trench. Do not use open trenches; they are subject to problems of algae, erosion, clogging by vegetation, and surface contamination.

4.4.3.2 Buried Pipes. For diameters up to 2 ft, perforated vitrified clay, concrete, cast iron, or tile drains laid with open joints, may be used. Bury the pipes in a trench and pack gravel around them. Trenches more than 20 ft deep are usually uneconomical.

a) For the design of perforations, joint opening, and gravel packing, use the same criteria as for wells.

b) The design velocity in collecting pipes should not exceed 2 fps.

c) Collect the water in a covered sump and pump it.

d) Provide manholes spaced at 100 to 300 ft to facilitate inspection and maintenance.

e) Valves should be placed at the end of the collecting pipes discharging into the sump, and thus providing a means for back flushing to improve the capacity and for isolation for repairs.

4.4.3.3 Tunnel or Gallery. For diameters from 2 to 5 ft, use concrete or masonry conduits with perforated openings constructed by open excavation or tunneling. Design strength requirements for buried pipes are applicable.

4.4.3.4 Underground Dam. Subsurface sheet piling, masonry, or chemically solidified barrier dams may be used in conjunction with other collection systems where groundwater is confined in a narrow valley. Locate the dam downstream from the collecting system. It must reach to an impervious formation, in order to seal off the underflow and store it for withdrawal by the upstream collector system.

4.4.3.5 Radial Type Collector. Buried perforated pipes, driven radially from a collecting sump, may be installed near a place of recharge from surface waters, and occasionally elsewhere. This type is best adapted to permeable alluvial aquifers. Yields may range from 300 to 14,000 gpm.

4.4.4 Skimming Wells. Horizontal wells, termed Maui wells, are the same type as the infiltration galleries in horizontal tunnels.

4.4.4.1 Locations. These wells are used when the seawater is in contact with the fresh groundwater on one or more sides at the following locations:

a) Islands, atolls, peninsulas, spits, or bars surrounded by the sea.

b) Artesian aquifers which outcrop under the sea.

4.4.4.2 Construction. Skimming wells should, if possible, be constructed above sea level, and near the thickest section of the fresh water lens so as to utilize the greatest available hydrostatic pressure and storage. In Pacific atolls, construction below sea level may be permissible to allow withdrawal at low tide.

4.4.4.3 Design. Basis of design is as follows:

a) The yield of a particular lens is generally no higher than half of the recharge rate, and can be much less.

b) The recharge rate may reach half the annual rainfall where rainfall exceeds 20 in. in a year, but may be as low as one percent of the rainfall where rains are less than 4 in. per yr. Exact relations will depend on vertical permeability, vegetative demands, and rate of rainfall and of losses through runoff.

c) Losses occur even without a draft on such lenses, through discharge to the sea and vegetative demands.

d) Because of the difference in density between fresh and seawater, a fresh water lens will extend 40 ft below sea level for each ft it rises above sea level.

e) The quantity stored at the close of the recharge season equals the horizontal area of deposit, times the average thickness of the fresh water lens, times the effective porosity of the aquifer. The effective porosity in these circumstances may range from 10 percent in loose sand to 30 percent in coral. The presence of impermeable layers or of large open channels greatly reduces the effective storage. On a long-term basis, not more than half the quantity stored is recoverable between recharge seasons.

4.5. Surface Water

4.5.1 Existence. The development of surface sources depends on hydrologic conditions and geographic features of the area. Refer to Water Quality and Treatment, Chapter 4 - Source Water Quality Management, AWWA, Fourth Edition; Soil Surveys prepared by United States Department of Agricultural, Soil Conservation Service; United States Geological Services Topographical Maps, stream flow data, and rainfall data.

4.5.2 Information Required. Use existing data, as far as practicable, before collecting field information. For the detailed data required in evaluating surface supplies, refer to Table 7.

Table 7
Information Required for Selection of Surface Water Supplies

CATEGORY	DETAILED DATA REQUIRED
Hydrologic data	Refer to USGS stream flow Data and Topographical Mapping.
Geographic data	Topographic map of drainage area. Cross-section and profiles of streams and rivers. (Not always required.) Depths, surface areas, storage capacity of ponds, lakes or reservoir sites.
Geologic data	At dam site. At intake site. At reservoir site.
Water quality	Chemical characteristics. Bacteriological content. Sources of pollution.

In addition to all public sources, consult private water agencies and available surveys of other agencies.

4.5.3 Evaluation of Supply. Conflicting uses which modify the safe yield include:

a) Conservation requirements, such as flood control, recreational uses (fishing, boating, bathing, and the like), and preservation of fish life

b) Pollution control requirements

c) Navigation requirements

d) Hydroelectric power requirements

e) Prior water rights

4.5.3.1 Safe Yield Determination

a) Natural Flow (Streams and Rivers). The minimum dry weather flow must equal:

(1) The peak demand when there is no distribution or storage reservoir.

(2) Maximum daily demand when there is adequate compensating storage.

b) Natural Storage (Lakes and Ponds). The yield from a natural supply should satisfy the average daily demand. In determining yield, regulatory restrictions on the decrease in water level may have to be considered.

c) Impounded Storage. The yield should satisfy the anticipated future average daily demand.

d) Rainwater Catchment. The minimum annual precipitation, less all losses, should satisfy the average daily demand. Adequate storage capacity must be provided.

4.5.3.2 Water Quality. The following factors are important:

a) Water examination (chemical, physical and bacterial analyses)

b) Sources of contamination:

(1) Domestic wastes

(2) Industrial wastes

(3) Sediments from soil erosion

(4) Hostile action

4.5.3.3 Limits of Economic Development. The following factors should be studied:

a) Cost policy of the Military

b) Anticipated expansion at the Military activity

c) Time required for the anticipated future demand to exceed the safe yield from surface sources

d) Design life of the structures, and design frequency of spillways.

4.5.4 Water Rights. Water rights for surface water often differ from those for groundwater. They are generally regulated at the state level, except that interstate rights are regulated by the Federal Government. Secure legal advice for the applicable doctrine:

a) Riparian,

b) Appropriation, or

c) Allocation.

4.5.5 Watershed Protection. Uses and activities in surface water supply watersheds may impact raw water quality and require higher levels of treatment. Recreational activities should only be allowed when adequate treatment is utilized. The protection of the watershed should be in accordance with all current U.S. EPA regulations regarding watershed protection.

4.6 Surface Water Collection Works

4.6.1 Intakes. Refer to Water Treatment Plant Design, Chapter 4, "Intakes," AWWA, and Recommended Standards for Water Works, Health Education Services.

4.6.2 Reservoirs

4.6.2.1 Selection. The selection should be based on the following factors:

a) Drainage areas must be adequate to provide the required flows.

b) Topography at the dam should provide ample storage capacity at minimum cost, and a good site for a spillway to pass the flood flow.

c) The geology at the dam should provide suitable materials for dam construction, safe foundation for the dam and the spillway, and tightness against excessive seepage.

d) Selection should avoid the following sites: densely inhabited areas, heavily wooded areas, large swampy areas, areas requiring major highway relocation, areas fed by silt-laden streams, and areas with many prior water rights.

e) Intakes should be located so that tributary streams and treated or untreated wastes cannot be short-circuited through the reservoir to the intake.

f) Sites should be as close as possible to the area served.

g) Plan for a gravity aqueduct from the intake to the point of delivery.

h) The site should have a minimum of shallow areas when flooded, since shallows encourage growth of weeds.

i) To reduce silting, seek the smallest practicable drainage area.

4.6.2.2 Reservoir Site Preparation. Before constructing dams and appurtenances, perform the following operations at the reservoir site:

a) Demolish and remove all structures below the high waterline. Consider removal of structures above the high waterline.

b) Clear and grub all trees, stumps, brush, weeds and grass below the high waterline. Clearing above this line may encourage an objectionable growth of underbrush.

c) Remove all sanitary waste and waste disposal structures, such as septic tanks and cesspools from the entire reservoir site.

d) Remove as much muck from swamps as possible, with emphasis below the high waterline.

e) Drain all pockets in marginal swamps.

4.6.3 Dams. For collateral reading, refer to Department of the Interior, Design of Small Dams.

4.6.3.1 Earthfill. Use earthfill dams wherever construction materials are available nearby and where a suitable spillway can be secured. A qualified expert in soil mechanics should be consulted to analyze soil samples taken at the site, and to advise on design and construction. The design of earthfill dams should fulfill the following requirements:

a) The materials should be stable under all probable conditions of moisture content.

b) The foundation material should have enough bearing capacity to support the loaded dam.

c) The dam should be resistant to percolation of water.

d) The embankment slopes should be protected against erosion due to wave action and surface runoff.

e) The freeboard should suffice to prevent overtopping of the dam during extreme flood flow, and damage due to frost penetration.

f) The design of earthfill dams should follow the criteria for compacted embankments in NAVFAC DM-7 Series on Soil and Foundations.

4.6.3.2 Rockfill. Use rockfill dams where rock is the only satisfactory material available. The dam should have a seepage-retarding membrane, either in or on the upstream embankment. Design this membrane to remain watertight while subject to temperature changes and other forces. All other requirements for earthfill dams are applicable.

4.6.3.3 Concrete or Masonry. Use a concrete or masonry gravity dam only where earthfill and rockfill types are not applicable and where the spillway must be incorporated in a strong dam structure. The design of these dams should fulfill the following requirements:

a) The dam must be stable against overturning, sliding, shear, uplift ice thrust pressure, and earthquake shocks.

b) The foundation must have enough bearing capacity to support the structure with the reservoir full.

c) The dam and the foundation must be leakproof.

d) The freeboard should suffice to prevent overtopping during extreme high flood flow and wave action.

4.6.4 Spillways. Provide adequate main and emergency spillways to protect dams against overtopping by floods. They may be side channel, chute, or ogee type.

4.6.4.1 Main Spillway. This appurtenance should:

a) Provide a capacity to pass a 100-year flood.

b) Be located, wherever possible, away from the intake and the dam.

c) Be built of concrete or stone, with sidewalls to protect the dam structures from damage by sprays and the high velocity in the spillway channel.

d) Be provided with an energy dissipater at its downstream end to reduce the velocity to a rate that is harmless to any downstream river channel on which the safety of the dam depends, or to any downstream structures.

e) Provide a smooth approach section such that the full design capacity of the spillway will be utilized.

f) Be provided with gated spillway openings only when:

(1) Positive gate operation is assured,

(2) Full-time staff attends the dam, and

(3) Good communications and flood routing information are available.

4.6.4.2 Stilling Basin. This basin should be used as the energy dissipater for the main spillway. Its design should fulfill the following requirements:

a) The floor should be set so that the conjugate water depth in the basin matches the tailwater elevation.

b) The length should embrace the hydraulic jump within the basin at maximum flow.

c) The basin should be concrete, with sidewalls to prevent the erosion of soils behind them.

4.6.4.3 Emergency Spillway. This unit should:

a) Provide a capacity, combined with the main spillway, to pass the maximum probable flood flow.

b) Be located away from the intakes and the dam.

c) Have its crest set at an elevation such that the design flood level of the main spillway will not be exceeded.

d) Have a low head discharge with a wide cross section to keep the maximum crest velocity low; except where no erosion from discharge will occur, when a fuse plug or washout type may be used.

e) Have its slope reduced, so as to cause velocities within the maximum allowable for the channel materials.

f) Have a smooth approach section.

g) Be constructed on firm material and, if an earth channel is used, always be well covered with grass and clear of trees, bushes, structures, and any other obstructions to flow.

h) Use flash boards to provide any additional storage or depth above the spillway crest. Special investigation of resultant hazards and associated problems will be required. Flash boards should be of the washout type. Use criteria in American Civil Engineering Practice, Volume 2, by R. W. Abbett.

4.6.5 Rainwater Catchment Areas. The site should be selected for the following desirable factors:

a) Topography presenting a large surface area where rainwater can be easily collected. Slopes greater than 0.01 (1.0 percent) are desirable, as is space for a ponding basin to store peak flows.

b) Absence of heavily wooded areas.

c) Absence of large swampy areas.

d) A minimum distance of at least 100 ft from the outer edge of the catchment or related structures to subsurface sources of contamination (such as septic tanks and cesspools) where the ground surface is used as a catchment area.

e) Locate as far from sources of air pollution as possible (for example, dust, soot, salt water spray).

4.6.5.1 Application. Such areas are to be used only:

a) Where there is no other adequate source of fresh water.

b) Rainfall is sufficient to supply the required yield.

4.6.5.2 Types

a) Open Ground Surface Area. The catchment area should be graded to facilitate collection of rainwater and to eliminate depressions causing ponding, and should be paved with impervious materials to prevent seepage losses. The collected waters should be conveyed to a closed storage reservoir.

b) Roof Surface Area. Such areas should be used for installations with small demand for water, or to supplement ground surface areas.

4.6.5.3 Structures

a) Ground Surface Paving. Selection of the type depends on soil conditions at the site. Use either concrete or soil cement.

b) Training Wall. Provide adequate training walls around the catchment area. Provide curbs and gutters outside the catchment for protection against erosion, scouring, and contamination during heavy rain.

c) Spillway. Provide an emergency spillway to prevent overtopping.

d) Ponding Basin. Where feasible, make the basin integral with the catchment area. Size it in conjunction with the peak flow rates and capacity for discharging to storage.

e) Discharge to Storage. Water may run to storage by gravity or pumping. Provide a blowoff to divert the initial slug of raw water; it may carry accumulated minerals or sediment. Provide an intake sump with bar racks of the grating type in front of the conduit.

f) Storage Reservoirs. Design to conform to requirements for underground storage in Section 8.

g) Fencing. Fence the catchment area.

4.6.5.4 Sanitary Protection. Catchment areas must be lime washed immediately after construction. Water treatment, filtration and disinfection are required; (for methods, refer to Section 6 on Treatment).

4.6.5.5 Data Required. Rainfall data should include monthly rainfall quantities and where available, the number of days of rain per month. Catchment characteristics needed are: slope, roughness, pondage, and discharge capacity.

4.6.5.6 Basis of Design. For each rainstorm, there is a loss of moisture due to surface detention, pondage, and evaporation. Rather than analyze by individual storms, proceed on the basis of the number of days of rain. The loss will range from 0.06 in. per day of rain for steep, smooth catchments free of pondage to 0.25 in. per day of rain for paved areas having slopes of 0.01 and the roughness of screened surfaces, with some minor pondage. In this range, choose an appropriate unit loss allowance. Where data on the number of days of rainfall are unavailable, allow a gross yield of 0.5 gal/sq. ft of catchment area per in. of rainfall.

a) Monthly Yield. For each month, multiply the loss allowance by the number of days of rain. Subtract this product from the month's rainfall to determine the gross yield.

b) Peak Rate. Check the peak rainfall rates and resultant flows against the outlet capacity. If a substantial part of the annual rainfall causes uncollectible spills, make allowance for this. An appropriate loss allowance for roof-gutter systems, or others where there are such losses, is 25 percent of the gross yield. Correct each month's value; rainy season corrections will probably be larger than those in drier months.

c) Storage. Plot a mass curve of the direct period on record and graphically determine the storage required on the basis of the desired net unit yield. From the unit yield and storage data, determine the area of catchment and the total storage required.

4.7 Nonpotable or Salt Water Systems

4.7.1 Utilization

4.7.1.1 Waterfront Fire Protection Cooling and Flushing Water. Separate nonpotable water supplies should be provided for active waterfront facilities. At active and repair berths and drydocks, cooling, flushing and fire protection requirements should be met using nonpotable fresh or saltwater supplies. Only one nonpotable system should be provided, and it should meet the requirements of the MIL-HDBK-1025 and MIL-HDBK-1029 Series. At inactive berths, salt or nonpotable water should be used, when available, for fire protection; if not available, potable water should be used. Nonpotable water supplies should be designed to preclude any possible contamination of potable water supply sources or systems. Saltwater systems, including distribution mains, should not be placed within a fresh water aquifer, as any leaks would contaminate the aquifer.

4.7.1.2 Condenser or Cooling Water. Use nonpotable systems for cooling and similar industrial uses when the quality of water is not a critical factor.

4.7.1.3 Demineralization or Distillation. Use nonpotable water for intake and waste sections of demineralization or distillation systems. The potable portion of such systems should be completely separated from nonpotable sections.

4.7.2 Precautions. Special precautions for nonpotable or saltwater systems are discussed below.

4.7.2.1 Cross Connections. Refer to AWWA Manual M14, Recommended Practice for Backflow Prevention and Cross-Connection Control.

4.7.2.2 Elevated Storage Tanks. For nonpotable supply storage tanks, use air gaps to prevent polluting the potable water system. Every inlet from the potable water system into the tanks should be placed at least 6 in. or two times the pipe diameter, whichever is greater, above overflow level. In other respects, use the criteria for tanks on potable water systems in Section 8.

4.7.2.3 Outlets. All outlets of a nonpotable water system must be marked appropriately.

4.7.3 Requirements. Criteria for requirements of nonpotable or saltwater systems are as follows.

4.7.3.1 Fire Protection. For fire protection of shore facilities, refer to MIL-HDBK-1008C.

4.7.3.2 Waterfront Operational Facilities. Requirements for fire protection and flushing/cooling water are given in MIL-HDBK 1025 Series.

4.7.3.3 Graving Docks. The demands for graving docks must be considered in the design or evaluation of overall station capacity. Refer to MIL-HDBK 1029/1, Graving Drydocks, for graving dock requirements.

4.7.3.4 All Other Uses. Uses other than those discussed previously should be as required by the process being served.

4.7.4 Intakes. The general criteria for fresh water intakes given in par. 4.6.1 are applicable with the following additional requirements.

4.7.4.1 Location. Keep suction lines short, but avoid proximity to sewer outfalls, storm drains, and areas subject to waterborne trash or refuse. Combine with condenser or cooling water intakes when feasible. The intake structure can be separate from the pump house.

4.7.4.2 Secondary Inlet. Provide emergency inlet or screen bypass at the bulkhead. Make the inlet accessible for manual operation.

4.7.4.3 Screening. All intakes should be screened as follows.

a) Traveling Water Screens. Traveling water screens should be considered for all saltwater intakes.

b) Fixed Screens. At small intakes, operating less than 2 hours per day, a series of fixed screens can be used. Follow the sequence and sizes of bar, coarse, and fine screens as given in Section 6. Framing and screening should be heavy, hot-dipped galvanized steel, corrosion-resistant alloy, or fiberglass when screens are not exposed to sunlight. Provide easy access for cleaning and maintenance.

4.7.5 Pumping. System pressure and capacity are determined by fire, flushing and cooling water requirements. The basic criteria for pumping stations are identical with those for fresh water stations given in Section 5 and Section 9 of this manual, except as discussed below.

4.7.5.1 Power. Steam turbine drives can be used if the pump station is in, or adjacent to, a central heating plant or power plant that uses steam-driven auxiliaries. Power must be available at all times. Where the seawater system is a main source of firefighting water, provisions should be made for either standby power or auxiliary drive by diesel power. Standby power or auxiliary drive units should be automatically supervised and thrown into operation, unless the pumping station is to be manned continuously.

4.7.5.2 Pumps. The use of cast iron for pumps, other than standby pumps, is prohibited for saltwater systems. Pump suppliers can be consulted for recommended materials based on service and pressure. However, designers should evaluate the corrosivity of the water and specify appropriate materials. Easy dismantling is essential for this type of service. Capacity of the standby power system or auxiliary drive system should provide at least 50 percent of the total pumping capacity, unless electric power is provided from two separate sources.

4.7.5.3 Alarms. Where the system will be in continuous service, provide low pressure alarms. If the pumps operate intermittently, the alarm system should be operative only when driving units operate, after a suitable time delay.

4.7.6 Distribution System. Use applicable criteria for potable water systems, Section 7. Include additional loops and branches required for graving docks and waterfront operational facilities.

4.7.6.1 Pressure. Provide pipe and fittings of a class suitable for the operating pressure, plus an allowance, based on detailed analysis, for water hammer. Assume a fouling factor in pipeline friction based on local experience. Where local data are unavailable, use a friction factor of n = 0.017 or Hazen-Williams coefficient of c = 100.

4.7.6.2 Materials. Materials for water mains should be selected from the following:

a) AWWA C104/A21.4, ANSI Standard for Cement-Mortar Lining for Ductile Iron Polyethylene Encasement for Ductile Iron Pipe Systems. AWWA C110/A21.10, ANSI Standard for Ductile Iron and Gray-Iron Fittings, 3 in through 48 in, for Water and Other Liquids.

b) AWWA C950, Glass-Fiber-Reinforced Thermosetting Resin-Pressure Pipe.

c) AWWA C900, Polyvinyl Chloride (PVC) Pressure Pipe 4 in. through 12 in., for Water, and 40 CFR Part 141.50.

1) AWWA C906, Polyethylene Pressure Pipe and Fittings 4 in. through 63 in.

Materials for exposed pipes under piers should be either flanged ductile iron or cement mortar lined, steel pipe; AWWA C205, Cement-Mortar Protective Lining and Coating for Steel Water Pipe--4 in. and Larger--Shop Applied. Steel pipe is preferable where insulation is required. Pipe shall have a 250 psi rating and be properly coated for corrosion protection.

4.7.6.3 Valves. Use butterfly valves having a 250psi rating constructed of materials resistant to corrosion by the source water. Refer to AWWA M44, Distribution Valves: Selection, Installation, Field Testing and Maintenance.

4.7.6.4 Construction. Check loads at joints, bends, fittings, valves and other necessary locations, and provide necessary tie-downs and blocking.

a) Location. Where pipes run under or inside of structures, provide access manholes in the structures.

b) Access. Provide blind flanges, hand holes, removable sections, and other types of openings into the piping for cleaning and inspection.

c) Protection Against Freezing. Perform a detailed analysis to determine if insulation or other type of protection is necessary. Allow for the lower freezing temperature of seawater.

d) Protection Against Wind Damage. Pipes suspended aboveground or on structural supports should be anchored to withstand wind velocities specified for the design of structures (refer to MIL-HDBK-1002 Series, Structural Engineering).

e) Protection Against Current/Tidal Action. Seawater intake structures and piping exposed to current/tidal action should be adequately protected.

f) Expansion/Contraction. Expansion/contraction requires detailed analysis to determine if provisions for expansion or contraction are necessary.

4.7.7 Corrosion and Fouling. Special criteria related to corrosion and fouling are outlined below.

4.7.7.1 Cast Iron. Cast iron, which is normally used for pumps and piping in potable water systems, is slowly attacked by seawater which removes the iron, leaving a graphite residue (graphitization). In quiescent water, this graphitized layer remains intact and protects against the penetration of water and further corrosion. This protective layer is soft, and high velocity flow in pumps or piping will remove it and expose fresh base metal to high-rate corrosion. Furthermore, the graphite particles are cathodic and can accelerate the corrosion of new cast iron brought into contact with them.

4.7.7.2 Cement Lined Steel and Cast Iron Pipe. Usually, cement lining is good protection against corrosion. However, the lining can be eroded by high velocity flow of sediment-bearing water, fouling organisms can break the lining away from the pipe wall, and impact and vibration at waterfront structures can weaken the lining.

4.7.7.3 Plastic Piping. There is no significant corrosion problem in the use of plastic piping and the pipe is not as susceptible to fouling as other nontoxic materials. Plastic pipe should be protected from ultraviolet radiation and properly supported when installed in exposed locations. When installed underground backfilling with selected material must be specified in order to prevent surface gouging. PVC piping for drinking has become suspect by the EPA (refer to 40 CFR Part 141.50).

4.7.7.4 Copper Based Materials. Copper based materials are commonly used on ships and other floating structures to overcome both corrosion and fouling. Costs and the rough use that this type of pipe will receive at shore installations may preclude its use in extensive distribution systems and particularly in large diameter pipes. Copper based materials are susceptible to corrosion by hydrogen sulfide.

4.7.7.5 Cathodic Protection. Details for cathodic protection design are given in MIL-HDBK-1004/10, Cathodic Protection. MIL-HDBK-1004/10 deals with cathodic protection for all buried metallic structures including water supply lines and storage tanks. For additional information refer to AWWA Manual M27 - External Corrosion, Introduction to Chemistry and Control, latest edition. This type of protection will probably control corrosion economically at the intake piping and structures, and in some cases may be feasible to use for protecting transmission lines. Consideration must be given to the effect on adjacent buried utilities.

4.7.7.6 Fouling. A fouling problem will exist in all saltwater handling systems. Fouling organisms may reduce corrosion by protecting the base material or accelerate it by breaking up protective coatings or corrosion films. Some barnacles are capable of penetrating bituminous coatings up to 1/4-in.) thick. An important additional point is that fouling organisms obtain a more secure hold on hard smooth surfaces than soft material. For example:

a) Barnacles adhere strongly to stainless steel.

b) Fouling organisms can be fairly easily removed from soft rubber.

c) Common protective paints, (nonantifouling) with hard, glossy finishes afford good foundations for fouling organisms while soft paint finishes do not.

4.7.7.7 Control of Fouling

a) Fine Screening. This method reduces the number of organisms entering the system; however, most fouling growths attach themselves at an early growth stage when they are small enough to pass through fine screens.

b) Chemical Treatment. Chlorination is the most common treatment used in saltwater handling systems, and is recommended. Chlorine cannot protect the sections of piping upstream of the point of application unless back-flushing is feasible. The method is fairly successful in piping or circulation systems. It may be relatively expensive to add a large dosage of chlorine to large volumes of water. This is often overcome by slug-feeding at high rates about 10 percent of the time of operation. Copper sulfate may also be useful in controlling fouling.

c) Antifouling Paints. These paints are in very common use for protection of exposed material. Almost all antifouling paints utilize copper because of its toxicity to waterborne organisms. Antifouling paints must be separated from a ferrous base metal by a primer coat to prevent interaction between copper and iron.

d) Velocity Control. Above certain velocities fouling organisms cannot anchor themselves on piping and/or pumps. Below the following approximate velocities, fouling will occur:

PIPE MATERIAL	LIMITING VELOCITY (approx. fps)
Glass	7
Plastic	8
Steel	11
Cement lining	15

It is not feasible to maintain these velocities in most sections of a distribution system.

4.7.7.8 Combined Control of Corrosion and Fouling

a) Desired Protection. On most systems, it is recommended that multiple protection be provided. A typical system would have an intake protected by a traveling screen, chlorination, and corrosion resistant or lined piping.

b) Copper Base Material. Not commonly used due to cost and the inability to stand rough handling.

Section 5: PUMPS

5.1 Pumping Installation Planning

5.1.1 Information Required. See Table 8 for the detailed data needed for design of pumping installations.

Table 8
Information Required for Pumping Installation Planning

CATEGORY	DETAILED DATA AND INFORMATION
Purpose of service	Transmission of water from water source. Pumping in the distribution system. Pumping to elevated storage tank. Pumping for fire protection. Booster pumping. Pumping service at treatment plant. Other miscellaneous pumping services.
Piping layout	Lengths, sizes, fittings.
Demand requirements	Maximum demand: Mgd or gpm. Average demand: Mgd or gpm. Minimum demand: Mgd or gpm. Variation in demand. Effect of storage on demand rates.
Static lift requirements	Static suction head or lift
Liquid characteristics	Static discharge heads Specific gravity Temperature Vapor pressure Viscosity pH Chemical characteristics Solids content
Power available	Type Characteristics

5.1.2 System Head Curve. Refer to Pumping Manual, Chapter 2, "Pump Performance and Characteristics," T.C. Dickenson, 9th Edition, for determining system head curve.

5.1.3 Pumping Arrangements. Select the pumping arrangement based on the types, applications, and limitations listed in Table 9.

Table 9
Applications and Limitations of Pumping Arrangements

TYPE OF ARRANGEMENT	WHERE TO USE	LIMITATIONS
Bypassing the discharge (all or part)	Not to be used for normal operation in a large installation, except during emergency when other arrangements are inoperative	Waste of power
Multiple pumps in parallel operation	Use this arrangement as a normal installation	Requires multiple pumps, and possibly jockey pump to pressurize system at low demands
Intermittent pumping with storage reservoirs riding on hydraulic gradient	Use this arrangement wherever possible	
Manual or automatic speed variation to control pump discharge	Use only if detailed cost study indicates feasibility	Usually expensive

5.1.4 Determining Pump Capacity. Determine single or multiple pump type as follows.

5.1.4.1 Single-Pump Installation. This type of installation may be used only for extremely small demands, when standby service is positively assured.

a) To meet the maximum daily demand where there is an elevated storage reservoir.

b) To meet the maximum daily demand where there is an elevated storage reservoir.

5.1.4.2 Multiple-Pump Installation. Use this arrangement normally; determine the capacity of each pump from a detailed study of various combinations to meet variations in demand. Provide at least three pumps. The necessary station capacity should be available with the largest pump out of service.

5.2 Selection and Installation of Pumps

5.2.1 Types and Applications. Refer to Pumping Manual, T. C. Dickenson, 9th Edition, or Hydraulic Institute Standards for information regarding proper application of pump types. Pump characteristic tables are provided in the Pumping Manual.

5.2.2 Pump Selection. Seek catalog information and guidance of several pump manufacturers in selecting a particular pump. Refer to Table 10 for the factors involved.

Table 10
Factors in Pump Selection

ITEM	DETAILS AND FACTORS
Pump characteristics	Capacity range (gpm) Discharge head range (feet) Characteristic curve (steepness, kinks) Efficiency Power input Speed (rpm) Specific speed Suction requirements
Pump construction	Conform to standards of Hydraulic Institute (HI) Pump materials must be suitable for liquids to be handled Bearing and seal construction
Space requirements	Compare vertical with horizontal type and select pump requiring least space, other factors being equal
Operating flexibility	Pump starting characteristics Pump priming requirements Behavior under parallel operation
Economy	Power Maintenance

5.2.3 Installation Requirements. Use applicable sections in the Hydraulic Institute Standards. Some typical pump stations are shown in American Civil Engineering Practice, Volume 2.

5.2.3.1 Pump Location. Except for submersible sump pumps, pump drives should not be placed in a pit or other location subject to flooding. Wherever possible, locate pumps so there is a positive suction head.

5.2.3.2 Piping Arrangement. Wherever possible provide loop headers or otherwise arrange piping for minimum interruption of service due to any one piping break. Where fire demand water is furnished, arrange to supply at least 50 percent of the system demand despite a possible break in any piping.

5.2.3.3 Suction Piping. Static lift should not exceed 15 ft, including all losses through suction piping due to the pump location. In all conditions of suction lift, a positive priming facility should be provided.

5.2.3.4 Valves. Valves at pumps should be arranged to provide for removing any pump unit from service without interruption to others.

5.2.3.5 Pressure Relief Valves. Provide a pressure relief valve or a small bleeder line on pump discharge, if the characteristics of the pump permit development of excessive pressure, or if damage to the pump could result from overheating because of operation with zero flow. This must be done when the pump discharges into a distribution system which does not include an elevated storage tank, or if the system includes an elevated tank that is protected against overflow. Review manufacturer's data for selection criteria required to prevent cavitation damage.

a) Recirculation Line. Where potable water is pumped from an underground reservoir, a recirculation line should be provided, discharging from the pressure relief valve into a properly checked reservoir fill line.

b) Fire Pumps. Pressure relief valves should be provided on fire pumps in accordance with National Fire Protection Association (NFPA) Standard No. 20, Installation of Centrifugal Fire Pumps.

5.2.3.6 Flexible Coupling. To relieve any strain transmitted to the pumps and to take up misalignment, piping near pumps should be provided with flexible couplings.

5.2.3.7 Vertical Pumps. Design criteria for vertical pumps are delineated below.

a) Wet Pit or Well Submergence. Use the value recommended by the pump manufacturer for operation at sea level with water at 70? F, and adjust the value for elevation above sea level and water above 70? F.

(1) Add 14 in. submergence for every additional 1,000 ft of elevation above sea level.

(2) Provide additional submergence for water temperatures above 70 degrees F, as follows:

TEMPERATURE degrees F	ADDITIONAL SUBMERGENCE in.
80	4
90	10
100	17
110	26
120	38
130	54
140	74
150	100
160	125
170	160
180	205
190	250
200	300

b) Vertical Booster Pumps. Vertical booster pumps aid in reducing space and piping requirements. Direct-connected and can-type units are suitable.

c) Intake Sump Design. Provide bar racks and screens to protect pumps, piping, valves, and fittings from debris and aquatic life. Dimensions of the sump should be such as to prevent vortex and turbulence, which are detrimental to pump performance. Use the HI Hydraulic Institute Standards as guides in design.

5.2.3.8 Priming Facilities. Use the requirements of the HI Hydraulic Institute Standards for planning priming facilities.

5.3. Power

5.3.1 Choice of Power. Factors affecting choice of power include dependability, availability, and economic considerations.

5.3.1.1 Types of Power. Select power from the following:

a) Electricity

b) Petroleum products (diesel oil)

c) Natural gas

d) Compressed air

e) Steam

5.3.1.2 Applications. For preferential choice and applications, refer to Table 11.

5.3.2 Standby. Standby power for pumps should be provided for all installations as described below.

5.3.2.1 Electric Power. Provide two separate sources (two separate feeders). Feeders should follow separate routes, and originate from separate substations or other sources.

5.3.2.2 Internal Combustion Engines. Provide internal combustion engines where there is no second separate electric power source. Such engines should provide a standby capacity which is equal to the required supply. Diesel engine-driven pumps should be installed above grade in accordance with NFPA

5.3.3 Drives. To select the proper drives to connect power to pumps, design for the following data:

5.3.3.1 Electric Drives

a) Torque Requirements. Use a constant torque motor for reciprocating and rotary pumps, and a variable torque motor for centrifugal pumps.

b) Alternating Current Motors. Use a squirrel-cage induction motor for 200 horsepower (hp) (149.2 kW) or less, at constant speed. Use a wound rotor induction or multi speed motor for 200 hp or less, when several different speeds are required. Where the power factor is important, use a synchronous motor for power above 200 hp.

c) Direct Current Motors. Use direct current (dc) motors only when speed adjustment is an important factor and when economic factors permit.

d) Enclosure. Use appropriate standards of the National Electrical Manufacturers Association (NEMA). General types and applications are as follows.

(1) Dripproof. Use in nonhazardous, clean surroundings.

(2) Totally enclosed, fan-cooled. Use in nonhazardous corrosive atmospheres containing dusts or high concentrations of chemicals, or where hosing down or splashing is encountered.

(3) Totally enclosed, explosion proof. Use in atmospheres containing potentially explosive gases, chemicals, or dust.

5.3.3.2 Selection of Other Drives. Apply the selection factors in MIL-HDBK-1003 Series, for internal combustion engines, gas turbines, steam turbines, and air compressors.

5.4 Pump Characteristics. Listed below are general guidelines to follow to determine the correct type of pump to use. Other sources to refer to for additional information include the Pumping Manual, T.C. Dickenson, 9th edition and Hydraulic Institute Standards.

5.4.1 Curves. Obtain characteristic curves from several manufacturers prior to the selection of a pump, including the following curves for centrifugal pumps: head capacity (H-Q), efficiency capacity (E-Q), brake horsepower capacity (BHP-Q), suction lift capacity, and net positive suction head (NPSH) required.

Table 11
Preferential Choice and Application of Pump Drive

POWER	CHOICE	DRIVE	APPLICATION
Electricity	First	AC motors DC motors	Primary power for stationary pumping
Diesel oil	First	Internal combustion engines	In isolated area for stationary pumping As emergency standby power source Portable pumping source
Natural gas	Second	Gas turbine or internal combustion engine	In isolated area for stationary pumping As emergency standby power source Portable pumping power source
Air compressor driven by motors or internal combustion engine	Second	Compressed air	At small installations for airlift pumps and for other pneumatic pumps

5.4.2 Head and Capacity. Choose the head and capacity to obtain the maximum efficiency for the range of operating conditions.

5.4.2.1 Axial Flow, Mixed Flow, Vertical Turbines, and Other Centrifugal Pumps. Check the points delineated below and select a pump accordingly.

a) Suitability of Curve Steepness. Determine the suitability of the curve steepness in the design range for the duty required.

(1) Does the pump provide (or prevent) the required variance in flow?

(2) Will the pump perform satisfactorily in parallel with others?

b) Curve Shape. Evaluate the curve shape on the basis of the following:

(1) Does the curve need to rise continually to the shutoff head?

(2) Is there any likelihood that the pump may be caught in a dip in the curve, resulting in unstable operation?

(3) Motor Overload. Do not allow motor overload at any possible operating point of the curve. Check the operating range, shutoff condition (if applicable), and low head condition.

5.4.2.2 Rotary, Reciprocating, and Jet Pumps. Study the manufacturers' rating curves, and select accordingly. Provide relief valves for all positive displacement pumps, between the pump and the first shutoff valve on the discharge line.

5.4.2.3 Airlift Pumps. Use airlift pumps for low lift service or when aeration is needed.

5.4.3 Speed. Selection of speed is governed by the criteria given below:

5.4.3.1 Centrifugal Pumps. The governing factors for centrifugal pumps include:

FACTORS	DESIGN PUMP LIFE (years) MORE THAN 10	DESIGN PUMP LIFE (years) LESS THAN 10
Maintenance costs	Low	High
Maximum speed (rpm)		
Operates less than 3 hpd	1,800	3,600
Operates more than 3 hpd	1,200	1,800

5.4.3.2 Rotary Pumps. Operating speeds should not exceed those approved by the manufacturer.

5.4.3.3 Reciprocating Pumps. Operating speeds should not exceed basic speeds prescribed in HI Hydraulic Institute Standards.

5.4.4 Specific Speed. Centrifugal pump selection is strongly influenced by efficiency and cavitation considerations. The specific speed of a particular pump at the discharge head and suction lift conditions should not exceed that prescribed for pumps of this type in HI standards, unless the application is of sufficient importance for military representatives to witness satisfactory operation- in-shop tests at higher specific speeds.

5.4.5 Net Positive Suction Head (NPSH). For centrifugal pumps, design of the intake system should ensure that the available NPSH exceeds the required NPSH, to prevent boiling under reduced pressure conditions and cavitation of the impeller. A reasonable margin of safety should be provided, at least 2 or 3 ft. Required NPSH can be obtained from the pump manufacturers, and available NPSH can be calculated using formulas in Hydraulic Institute Standards.

5.4.6 Lubrication. The choice (oil, grease, or water) and treatment should be consistent with the bearings used, as follows:

a) Oil for sleeve bearings.

b) Grease for antifriction bearings.

c) Water where the heat generated is excessive.

d) Lubrication to be applied in accordance with the manufacturer's instructions.

e) The system must prevent entry of oil or grease into a potable water supply.

f) For vertical pump line shafts, use rubber bearings and water lubrication.

5.4.7 Seals. Mechanical seals should be used where corrosive or volatile liquids are handled. Stuffing boxes should be properly packed and sealed by a sealing liquid in accordance with the manufacturer's instructions.

5.4.7.1 Water Seal. An independent water seal supply, not connected to the potable water system or a potable water supply protected by an air gap or backflow preventer, should be used where the water quality or pump characteristics prevent a self-sealing system as follows:

a) When the suction lift exceeds 15 ft.

b) When the discharge pressure is less than 23 ft.

c) When the pump handles hot water.

d) When the water is muddy, sandy, or gritty.

5.4.7.2 Stuffing Box Water Cooling. Cooling water should be applied to the stuffing box jackets where pumps operate at a high stuffing box pressure.

5.4.8 Surge Prevention. Surge or water hammer, produced by a sudden change of flow in the pumping system, should be carefully studied. For large, high pressure systems, the help of a qualified expert is recommended; and his recommendation should be incorporated into the design.

5.4.8.1 Methods of Control. Surges are handled by one or more of the following methods:

a) Moderating the valve closure time by either a manual or automatic valve controller;

b) A surge tank with a free water surface;

c) An air chamber on the discharge line;

d) A surge suppressor;

e) A surge relief valve;

f) A vacuum relief valve.

Section 6: TREATMENT

6.1 Guidance and Methods

6.1.1 Guidance. At permanent and temporary installations, disinfection by chlorination, chloramination, or other means will be applied to all water for potable uses, except from municipal or private water supply sources which conform to the bacteriological criteria set forth in Section 3. Refer to CFR 40 for additional treatment beyond disinfection.

6.1.1.1 Field Bases. Disinfection should be applied to all water before use. Additional treatment should be provided to naturally contaminated water. Special decontamination treatment should be applied to chemically contaminated water in addition to regular treatment.

6.1.2 Related Criteria. For design criteria of boiler feed water and power plant water supplies in central heating and power plants, refer to Water Conditioning in the MIL-HDBK-1003 Series on Mechanical Engineering.

6.1.3 Methods. Factors affecting the selection of treatment methods include: quality of water supply source, quality of desired finished water, dependability of process equipment, ease of operation, flexibility in reacting to changing water quality, space for construction, generation of wastes, and capital and operating costs. Refer to Water Quality and Treatment, Chapter 3, “Guide to Selection of Water Treatment Processes,” AWWA, Fourth Edition. Table 3.1, “General Effectiveness of Water Treatment Processes for Contaminant Removal,” provides the effectiveness of treatment processes such as aeration and stripping, coagulation, sedimentation, filtration, lime softening, ion exchange, membranes, disinfection for primary contaminates (microbial, turbidity, inorganic, organic), and secondary contaminants.

6.1.3.1 Application of Chemicals. Refer to pars. 6.7, 6.8, and 6.12 for chemicals to be used.

6.1.3.2 Pilot Study. For all permanent installations where water is to be handled by processes not adequately tested in nearby plants, operating on a similar water supply, a pilot study should be conducted to determine both the efficiency and arrangement of proposed treatment used.

6.1.4 Materials of Construction. To the maximum practical extent, use materials that are standard in ordinary engineering practice. Special materials may be used, where economy allows, or conditions dictate, to provide needed corrosion resistance or other characteristics especially required in parts of the treatment works.

6.1.5 New Devices. New treatment devices may be used only:

a) Where there are special needs that cannot be met by generally accepted methods, and

b) After testing by an impartial research or development organization has established their usefulness and dependability.

6.2 Screening

6.2.1 Types and Application. Bar racks with 1 1/2 - to 2-in. openings should be used to keep the large floating debris out of intake conduits, and for all intakes to low lift pumping stations.

6.2.1.1 Coarse Screens. For water to be filtered, use screens with 1-in. mesh to remove the small floating debris, vegetation, and fish that cannot be handled by bar racks.

6.2.1.2 Fine Screens. Use fine screens as recommended in Water Treatment Plant Design, AWWA, third edition. The water velocity in net screen openings should be less than 2.0 feet per second (ft/s) at maximum design flows and minimum screen submergence.

6.2.1.3 Traveling Water Screen. Use this type at freshwater intakes following the bar racks; or at treatment plants to remove high concentrations of coarse suspended or floating matter.

6.2.2 Materials of Construction. In fresh water, use steel frames for construction of screening.

6.3 Aeration. Refer to Water Treatment Plant Design, Chapter 5, “Aeration and Stripping,” AWWA, third edition; Recommended Standards for Water Works, Part 4.5, “Aeration,” Health Education Services, 1997 Edition; and Water Quality and Treatment, Chapter 5, “Air Stripping and Aeration,” AWWA, fourth edition.

6.4 Sludge Removal. Sludge removal is generally with mechanized sludge collectors, although it may be manual in some installations. If manual, provide at least two basins so that one basin may be taken out of service for cleaning without interruption of operation. Provide for hydraulic removal of settled solids by draining and flushing if possible, otherwise by manual load-and-haul. Refer to par. 6.11 for further guidance.

6.5 Coagulation and Sedimentation. Refer to Water Treatment Plant Design, Chapter 6, “Mixing, Coagulation and Flocculation,” Chapter 7, “Clarification,” AWWA, third edition; and Water Quality and Treatment, Chapter 6, “Coagulation Processes: Destabilization, Mixing, and Flocculating,” Chapter 7, “Sedimentation and Floatation,” AWWA, fourth edition.

6.5.1 Materials of Construction

a) Concrete. Use concrete for all permanent installations constructed on-site.

b) Steel. Use steel only for temporary units, factory prefabricated units, or small circular basins. It may be used for internal parts of a solids contact reactor, but for permanent installations, provide adequate corrosion protection.

6.6 Filtration. Refer to Water Treatment Plant Design, Chapter 8, “High Rate Granular Media Filtration,” Chapter 9, “Slow Sand and Diatomaceous Earth Filtration,” AWWA, third edition; and Water Quality and Treatment, Chapter 8, “Filtration,” AWWA, fourth edition.

6.6.1 Filtered Water Storage. Provide filtered water storage (clear well) in accordance with Recommended Standards for Water Works, Part 7, “Finished Water Storage,” Health Education Services, 1997 edition. Chlorine contact time (CT) should be in accordance with the requirements of the 40 Code of Federal Regulation (CFR) Part 141, and U.S. EPA National

Drinking Water Regulations. Refer to Water Treatment Plant Design, Chapter 10, "Oxidation and Disinfection," AWWA, third edition, for additional information relating to disinfection requirements.

6.7 Disinfection. Refer to Water Treatment Plant Design, Chapters 10, "Oxidation and Disinfection," Chapter 15, "Chemicals and Chemical Handling," AWWA, third edition; Water Quality and Treatment, Chapter 14, "Disinfection," AWWA, fourth edition, AWWA Manual M20, Water Chlorination Principles and Practices; and Recommended Standards for Water Works, Part 4.3 and Part 5; Health Science Group, 1997 edition. Disinfection should be in accordance with all regulations (including CT) as published in the 40 Code of Federal Regulation (CFR) Part 141.

6.7.1 Well Disinfection. Refer to AWWA Manual M21, Groundwater, AWWA Standard A100, Water Wells; and AWWA Standard C654, Disinfection of Wells, for well disinfection requirements.

6.8 Softening

6.8.1 Softening Processes. Refer to Water Treatment Plant Design, Chapter 11, "Lime Softening," and Chapter 12, "Ion Exchange Processes," AWWA, third edition, for detailed design criteria. For general design criteria refer to Recommended Standards for Water Works, Part 4.4, Health Education Services, 1997 edition.

6.8.2 Design Features. The most desirable total hardness for potable water supplies is about 100 ppm, with a carbonate hardness not less than 40 ppm. Water softer than 100 ppm total hardness is often corrosive. For water used only for domestic purposes, excessive hardness causes increased usage of soap and decreased lifetime of water heaters. There is no recognized, unacceptable upper limit for hardness, and the decision to soften can be based on economic analysis, consumer preference, or the judgment of the designer. The health effects of added sodium should be considered in evaluating any water softening program.

For a boiler water conditioning, hardness requirements and softening techniques are discussed in MIL-HDBK-1003 Series.

6.9 Special Treatment

6.9.1 Iron and Manganese Removal. Refer to Recommended Standards for Water Works, Part 4.5, Health Education Services, 1997 edition; and Water Quality and Treatment, Chapter 10, "Chemical Precipitation," AWWA, fourth edition.

6.9.2. Taste and Odor Control. Several treatment processes can control taste and odor. These processes include; copper sulfate treatment, aeration, activated carbon, chlorine dioxide, and ozone. For guidelines regarding these treatment processes refer to Recommended Standards for Water Works, Part 4.9, Health Education Services, 1997 edition; Water Quality and Treatment, AWWA; and AWWA Standards B600, Powdered Activated Carbon; B601, Sodium Metabisulfite; B602, Copper Sulfate; B603, Potassium Permanganate; and B604, Granular Activated Carbon, AWWA.

6.9.3 Corrosion and Scale Control. Refer to Water Quality and Treatment, Chapter 17, Internal Corrosion and Deposition Control, AWWA, fourth edition; and AWWA Scale and Corrosion Control Standards B501 through B505, B510 through B512, and B550.

6.9.4 Fluoridation. Refer to Recommended Standards for Water Works, Part 4.7, Fluoridation, Health Education Services, 1997 edition; Water Quality and Treatment, Chapter 15, "Water Fluoridation," AWWA, fourth edition; and AWWA Standards B701, Sodium Fluoride; B702, Sodium Fluorosilicate; and B703, Fluorosilicic Acid, AWWA.

6.9.4.1 Standby. It is not necessary to provide standby equipment for fluoride addition or removal since a short-term interruption in treatment for repairs and maintenance is not considered detrimental to the long-range effects of this type of treatment.

6.9.5 Reverse Osmosis Treatment. Reverse Osmosis can be used for the removal of all of the inorganic compounds listed in 40 Code of Federal Regulations (CFR) Part 141 through 143. Treatment units are typically sized after conducting pilot studies, particularly when units are being used for the removal for specific inorganics. Brine solutions produced during treatment can be discharged to a sanitary sewer, to a brine evaporation pond, or in some cases to a watercourse such as a river or body of salt water. Refer to Recommended Standards for Water Works, Health Education Services,1997 edition; and Water Quality and Treatment, Chapter 11, "Membrane Processes," AWWA, fourth edition.

6.9.6 Heavy Metals Removal. Heavy metals listed in 40 Code of Federal Regulations Part 141 through 143 can be removed by a number of treatment techniques, including reverse osmosis, alum or ferric coagulation, lime softening, anion exchange, and cation exchange. Guidance on removal capabilities of these processes for various heavy metals is presented in EPA-600/8-77-005, Manual of Treatment Techniques for Meeting the Interim Primary Drinking Water Regulations, and EPA-600/2-79-162a, Estimating Water Treatment Costs, Volume 1, Summary.

6.10 Saltwater Conversion

6.10.1 Application. Where freshwater supplies are not available, some means of saltwater conversion must be provided.

6.10.2 Treatment Processes. Select one of the treatment techniques listed in Tables 12 and 13. Review recommendations of manufacturers to develop criteria for design. Refer to reports of the Office of Saline Water, U.S. Department of Interior, for descriptions of processes. For additional information regarding membrane processes refer to Water Treatment Plant Design, Chapter 13, "Membrane Processes," AWWA, third edition; Water Quality and Treatment, Chapter 11, "Membranes," AWWA, fourth edition; and AWWA Manual M38, Electro dialysis and Electro dialysis Reversal.

6.11 Disposal of Wastes From Water Treatment Plants. For information regarding disposal of wastes refer to Water Treatment Plant Design, Chapter 17, "Process Residuals," AWWA, third edition; Water Quality and Treatment, Chapter 16, "Water Treatment Plant Waste Management," AWWA, fourth edition; and Recommended Standards for Water Works, Part 4.11, "Waste Handling and Disposal," 1997 edition.

Table 12
Characteristics of Salt Water Conversion Equipment - Technical

	Process					
	Electro dialysis	**Reverse Osmosis**	**Flash Distillation**[1]	**Submerged Combustion Distillation**	**Submerged Tube Distillation**[1]	**Vapor Compression Distillation**
Equipment Required	Prefilter, Electro dialysis stack, pumps, controls	Prefilter, feed pumps, reverse osmosis membranes and modules, product water degasifier, and controls.	Evaporator, boiler, air ejector vacuum system, chemical treatment equipment, pumps, controls.	Evaporator, cyclone separator, air-cooled condenser, air compressor, engine, distillate neutralizer, pumps, controls.	Evaporator, boiler air ejector vacuum system chemical treatment equipment, pumps, controls.	Diesel engine or electric motor, heat exchanger evaporator, starting heater, pumps, controls.
Characteristics						
Max raw water TDS,[2] ppm	15,000	None	None	None	None	None
Finished water TDS, ppm	Variable	Variable	2-10	10-100	2-10	0.5-10
Waste to product water ratio	0.1-1.0	0.33-1.0[7]	10-20	0.5-1.0	15-30	0.5-1.0

Table 12
Characteristics of Salt Water Conversion Equipment - Technical

	Process					
	Electro dialysis	**Reverse Osmosis**	**Flash Distillation**[1]	**Submerged Combustion Distillation**	**Submerged Tube Distillation**[1]	**Vapor Compression Distillation**
lb steam per gal product water	None	None	3-5	None	3-5	None
Shaft hp per 1,000 gpd capacity	1/2-2	1.1-2.1[4]	1	6-8	1	6-20
Operating temperature						
Water	See Footnote 5	See Footnote 6	145-175 degrees F	180-195 degrees F	145-175 degrees F	215 degrees F
Heat source	None	None	215-227 degrees F	Flame	215-227 degrees F	230 degrees F
Total input energy, Btu per gal product water	55[3,8]	68-130[4]	5,000-6,000	2,000-3,000	5,000-6,000	700-1,500

[1]Chemical treatment required for corrosion and scale control.
[2]Total dissolved solids.

Table 12
Characteristics of Salt Water Conversion Equipment - Technical

	Process					
	Electro dialysis	**Reverse Osmosis**	**Flash Distillation**[1]	**Submerged Combustion Distillation**	**Submerged Tube Distillation**[1]	**Vapor Compression Distillation**

[3]Brackish water, 5,000 ppm, TDS removed.
[4]For brackish water, hp/1,000 gpd is 0.04-0.07, and total input energy is 24-42 Btu/gallon of product water.
[5]Maximum water temperature 100 degrees F.
[6]Maximum water temperature 86-122 degrees F, depending on type of membrane
[7]Recommended standards for water works.
[8]Per Energy equation of Water Treatment Membrane Processes, AWWA (Page 12.40).

Table 13
Characteristics of Salt Water Conversion Equipment - Descriptive

Process	Energy Source	Method of Energy Transfer	General Description
Electrodialysis	Electrical	Potential difference and ion and current flow.	Migration of the ions to be removed is induced by the potential difference across the brine solution. Selective membranes allow either positive or negative ions to pass through, thus providing alternate channels of demineralized and highly mineralized water.
Reverse Osmosis	Electrical	Pressure across a semi-permeable membrane.	Membranes are used which allow water to pass, but reject the passage of positive and negatively charged ions, high pressure is used to counteract the natural osmotic pressure across the membrane, demineralized water and a highly mineralized waste streams are produced
Flash distillation	Waste or exhaust steam	Heat exchanger outside of evaporation vessel	Similar to submerged tube, below, except that the main heat input is in an external exchanger where no evaporation takes place. Water flashes into steam in the evaporator vessel away from hot coils, thus reducing sealing.
Submerged combustion distillation	Gas or liquid fuel	Combustion takes place in the evaporation vessel.	Fuel plus compressed air burn in evaporator. Combustion products are directed through the brine, heating and causing evaporation. Exhaust gases, mixed with steam, flow through a separator. Heat is recovered from condensate.

Table 13 (Continued)
Characteristics of Salt Water Conversion Equipment - Descriptive

Process	Energy Source	Method of Energy Transfer	General Description
Submerged tube distillation	Waste or exhaust steam	Steam coils in the evaporator.	Original marine equipment: heat exchanger is the evaporator vessel. Steam flows through coils in the evaporator. Low pressure (2 psia) maintained in the evaporator. Heat recovered form condensate heats incoming brine. Noncondensing waste gases evacuated by air ejector.
Vapor compression distillation	Compressor (also auxiliary heat)	Vacuum applied on evaporation side, compression on the condensate side	Initial heat added through auxiliary heater. Subsequent maintenance of low pressure in the evaporator causes brine to flash into steam. Heat is recovered from compressed vapor and transfers energy to brine

6.12 Chemical Feeding and Handling

6.12.1 Guidance. Equipment should be as simple as possible. In any installation or facility, equipment procurement should be limited to the smallest practicable number of manufacturers.

6.12.1.1 Standardization. Equipment should be standardized wherever possible. Use identical or similar components to the maximum extent. Feeding equipment should be homogeneous (that is, all self-powered, all pneumatic, etc.).

6.12.1.2 Equipment Accuracy. Equipment accuracy tolerances should be as low as possible consistent with the functions desired.

6.12.1.3 Equipment Ranges. Before selecting equipment, the required maximum and minimum capacities should be computed, and ranges should be kept as narrow as possible for any piece of equipment.

6.12.1.4 New Products. New products and applications are constantly being developed. Approval or advice on their uses must be requested from Naval Facilities Engineering Command Criteria Office or HQ AFCESA/CESC.

6.12.2 Chemicals. All chemicals used in water treatment operations should meet purity requirements of American Water Works Association (AWWA) standard specifications. Design should be based on the assumption that chemicals will be purchased in normal shipping containers (such as bags, drums, cylinders, or carboys) rather than bulk car or truckloads. Functions of various chemicals and chemicals strengths are provided in Water Treatment Plant Design, Appendix A, “Properties and Characteristics of Water Treatment Chemicals,” AWWA, third edition.

6.12.2.1 Handling and Storage. Refer to Water Treatment Plant Design, Chapter 15, “Chemicals and Chemical Handling,” AWWA, third edition; Recommended Standards for Water Works, Part 5, “Chemical Application,” Health Education Services, 1997 edition.

6.12.2.2 On-Site Generation and Feeding Equipment. For ozone, hypochlorite, and chlorine dioxide refer to Water Treatment Plant Design, Chapter 10, "Oxidation and Disinfection," AWWA, third edition; Recommended Standards for Water Works, Part 5, "Chemical Application," Health Education Services, 1997 edition.

6.12.2.3 Chemical Feeders. Refer to Water Treatment Plant Design, Chapter 15, Chemicals and Chemical Handling, AWWA, third edition.

6.12.2.4 Safety Precautions. Provide the following safety factors, as a minimum:

a) First aid kits.

b) Continuous toxic gas monitors with alarms and pressure demand self-contained breathing apparatus (SCBA) for emergency gas situations.

c) A readily accessible potable water supply to wash away chemical spills including emergency deluge shower and eyewash facilities located within easy access to those in need. Recommended Standards for Water Works, 1997 edition, suggest that a water holding tank that will allow water to come to room temperature should be installed in the water line feeding the deluge shower and eye washing device. Other methods of water tempering can be considered on an individual basis.

d) Special handling clothing and accessories, such as gloves, goggles, aprons, and dust masks.

e) Adequate ventilation. For facilities using gaseous chlorine or ammonia (chloramines), and exhaust fan for ventilation needs to be located near the floor, with intake near ceiling on opposite wall.

f) No electrical convenience outlets in activated carbon storage or feeding rooms. Store activated carbon in a separate room with adequate fire protection.

g) Entry into confined spaces will require adherence to a gas free engineering program. Refer to 29 CFR Part 1910 for regulations regarding entry into confined spaces.

6.12.2.5 Chemical Feeder Capacity and Standby Requirements. Base feeder capacity on maximum expected instantaneous flow and dosage. Essential (noninterruptible) chemical feeders such as disinfection units must have a standby unit having capacity equal to the largest unit. The need for standby units or other treatment processes depends on raw water quality. Where two chemical feed systems could use the same spare chemical feeder, one standby unit to serve both is adequate. Refer to EPA-430-99-74-001, Design Criteria for Mechanical, Electrical and Fluid System and Component Reliability.

6.12.3 Sampling. Except where raw water quality is highly variable during short time periods, composite sampling is usually not necessary for raw water. Composite sampling or continuous monitoring may be desirable for certain parameters in treated water, such as turbidity. Turbidity, chlorine residual, suspended solids, alkalinity, hardness, fluoride, and pH are the normal process control variables in potable water treatment. These are measured at least once per operating day. Other parameters that are measured quarterly, or annually are total trihalomethanes (TTHM), heavy metals, specific herbicides, pesticides and synthetic organics, and total organic carbon (TOC). Frequency of sampling these parameters depends on local conditions and regulatory requirements. Sample for Total Coliform as per U.S. EPA requirements as stated in 40 CFR Part 141.

6.12.4 Analytical Methods. Refer to APHA Standard Methods for the Examination of Water and Wastewater and AWWA Manual M12, Simplified Procedures for Water Examination, for laboratory procedures. In addition to standard laboratory methods, continuous monitoring is often required or desirable for certain water quality parameters.

6.13 Metering, Instrumentation, and Control. Refer to Water Treatment Plant Design, Chapter 20, “Process Instrumentation and Controls,” AWWA, third edition; AWWA Manual M2, Automation and Instrumentation; and AWWA Standard Series C700, Meters.

6.13.1 Guidance. Devices and systems should be as simple as possible. In any installation or facility, equipment procurement should be limited to the smallest practicable number of manufacturers.

6.13.1.1 Standardization. Equipment should be standardized wherever possible. Use identical or similar components to the maximum extent. Instrumentation and control equipment should be homogeneous (that is, all self-powered, all pneumatic, and so forth).

6.13.1.2 Equipment Accuracy. Equipment accuracy tolerances should be consistent with the functions desired.

6.13.1.3 Equipment Ranges. Before selecting equipment, the required maximum and minimum capacities should be computed, and ranges should be kept as narrow as possible for any piece of equipment.

6.13.1.4 New Products. New products and applications are constantly being developed. Advice on application and use should be requested from Naval Facilities Engineering Command Criteria Office or HQ AFCESA as appropriate.

6.13.2 Information Required. Obtain the following information to assist in equipment selection:

a) Type of treatment.

b) Chemical, physical, and bacteriological qualities of raw water, and actual variations; treated water, permissible limits.

c) Variations of flow rate or demand for raw water or waste, treated water or waste.

d) Ranges of other related variables.

e) Size of plant.

6.13.3 Primary Measuring Devices. Primary measuring devices are required at significant locations in water supply systems to sense and measure flow, pressure level, temperature, weight, pH, and other process variables essential to proper operating control and evaluation of plant performance. See Table 14 for examples of locations of measuring devices and types of measurements.

6.13.3.1 Use Limitations. Different types of measuring devices are available for each application. See Table 15 for a listing of primary devices and examples of their application. The listed "capacity" of a device includes most sizes and types of the device that are available. The "range" is the useful turndown-ratio of a particular device.

6.13.3.2 Discrete vs. Analog Devices. Alarm functions and many control functions require only the presence or absence of a process variable input for their operation. For example, a sump pump may start if the liquid level is above a certain point or a tank heater may start if the temperature is below a selected point. Control these functions by discrete devices such as flow switches, temperature switches, level switches, and pressure switches. If the actual status of the process variable is required, rather than on/off, for indication or control, an analog primary device should be used. Some alarm switches are not included in the tables; for example, clarifier torque switches, speed switches, and other equipment protection switches that are normally supplied with the equipment.

6.13.4 Instrumentation. Instrumentation covers all secondary instruments (such as gages, indicators, recorders, or totalizers) needed for efficient operation of water supply systems. Information sensed by a primary device is translated by instruments into an operator usable form. Most analog primary devices require secondary instruments, although a few (such as displacement meters) contain built-in counters. Instrumentation should be used only where operating convenience and cost savings outweigh added maintenance needs. Data logging devices should be considered where cost can be offset by reduced operating manpower needs. See Table 14 for recommended instrumentation usage. Refer to Water Treatment Plant Design, Chapter 20, “Process Instrumentation and Controls,” AWWA, third edition.

6.13.4.1 Use Limitations. Instruments may be obtained in any combination to total, indicate, or record the information developed by primary devices. Other more sophisticated forms of instruments (such as summation and multiplication of variable) are possible, but are not normally needed.

6.13.4.2 Transmission. Refer to AWWA Manual M2, Automation and Instrumentation, for information regarding pneumatic and electrical controls. Select means of transmitting information from primary measuring devices to secondary instruments from the following:

a) Mechanical. Transmission distance is limited to a few feet. Consider the effects of corrosion, wear, or icing on mechanical linkages.

b) Pneumatic. Transmission distance can be up to 1,000 ft. Reaction time of pneumatic loops is relatively long if transmission distance is long.

d) Electrical. There is no limitation on distance. Analog signals may require amplification for transmission distances greater than 1,000 ft.

6.13.4.3 Remote Indication. Remote indicators should provide the operator with the status of any function necessary for remote operation of the plant. Panel lights should indicate the on/off status of pumps or other discrete devices, alarm functions and operator-actuated functions (for example, initiate backwash, fill day tank).

6.13.5 Controls. Refer to Water Treatment Plant Design, Chapter 20, “Process Instrumentation and Controls,” AWWA, third edition; and AWWA Manual M2, Automation and Instrumentation. Controller devices are needed to regulate the functions of equipment throughout the process. Consider automatic controls where significant improvement in performance will result, or where cost can be offset by reduced operating manpower needs. Otherwise, keep controls as simple as possible. Wherever feasible, use fixed or manual controls (for example, weirs, launders, siphons, or throttling valves) in preference to mechanical devices, and direct acting controls (for example, float valves) in preference to electrically or pneumatically actuated devices. Always consider effects of possible control malfunctions. Controls may be classified by the degree of automation (see Table 14).

6.13.5.1 Manual. Use manual control where the operator will start, stop, or adjust rates of operations based on instrument observations, laboratory tests, or indicated conditions.

6.13.5.2 Automatic. Use automatic control to start, stop, or regulate rates of operations automatically in response to changes in a measured variable or other input. All equipment should also have manual control to override automatic control regardless of the degree of automation provided.

6.13.5.3 Design Considerations. Many controls combine manual and automatic operations. The operator may initiate an automatic-timed cycle backwash system, or adjust set points of a proportional controller based on instrument observation. Controls that seldom require adjustment (rate of flow to filters, for example) should be manual. Controls requiring frequent adjustment (starting sump pumps, proportional chemical feeding) should be automatic. Decisions on whether the automation is on/off-timed cycle, or proportional, should be based on analysis of plant requirements.

Table 14
Metering, Instrumentation and Control Requirements
for Water Supply and Treatment

Location and Use	**Type of Measurement**	**Type of Instrument Readout**[1]	**Range of Measurement and/or Readout**	**Controls**	
				Item Regulated	**Type**
Source of Supply: Surface (river or reservoir): Intake	Level	Indicator (0) Recorder (0)	Depends on site. Cover extreme levels.	None	
Diversion Structure	Flow	Recorder (0)	1 to 4	None	
Groundwater: Pump discharge	Pressure	Indicator (E)	0 to 1, 5 times shutoff pressure	None	
Well	Level	Indicator (E)	Static level to pump bowls	None	
Pumping and Conveyance: Low Service pump discharge	Pressure	Indicator (E)	0 to 1, 5 times shutoff pressure	None	

Table 14 (Continued)
Metering, Instrumentation and Control Requirements
for Water Supply and Treatment

Location and Use	**Type of Measurement**	**Type of Instrument Readout**[1]	**Range of Measurement and/or Readout**	**Controls**	
				Item Regulated	**Type**
Raw or treated water pipeline	Flow	Indicator (E) Totalizer (E) Recorder (0)	1 to 4	Chemical feeds, disinfection, flow splitting	Proportional automatic(0)
Coagulation - Clarification: Settling Basin	Level pH	Indicator (0) Indicator (0) Recorder (0)	Depth of basin 0 to 14 units	None Chemical feeds	Automatic(E)
Filtration: Filter Effluent	Flow Turbidity pH	Indicator (E) Recorder (0) Indicator (0) Recorder (0) Indicator (0) Recorder (0)	1 to 4 1 to 100 0 to 14 units	Filtration Rate [2] Time for backwash Chemical feed	Automatic(E) Automatic(E) Automatic(E)
Filter Headloss	Pressure differential	Indicator (E) Recorder (0)	1 to 3	Time for backwash	Manual(E)
Filter Backwash	Flow Turbidity	Indicator (E) Recorder (S) Indicator (0)	1 to 4 1 to 100	Backwash rate Backwash rate and length	Manual(E) Automatic(0) Automatic(0)
Sand Expansion	Level	Indicator (S)	1 to 1.5	Backwash rate	Manual
Surface Wash	Flow	Indicator (S)	1 to 4	Surface wash rate	Manual(E)

Table 14 (Continued)
Metering, Instrumentation and Control Requirements
for Water Supply and Treatment

Location and Use	**Type of Measurement**	**Type of Instrument Readout[1]**	**Range of Measurement and/or Readout**	**Controls**	
				Item Regulated	**Type**
Washwater Storage Tank	Level	Indicator (E) Recorder (S)	Depth of Tank	Washwater makeup	Automatic(E)
Chemical Softening: Softening unit	Flow pH	Indicator (E) Totalizer (E) Recorder (0) Indicator (E) Recorder (0)	1 to 4 0 to 14 units	Chemical feed Chemical feed	Manual(E) Automatic(0) Manual(0) Automatic(0)
Recarbonation unit	pH	Indicator (E) Recorder (0)	0 to 14 units	Chemical feed	Manual(0) Automatic(0)
Ion Exchange Softening: Influent or Effluent line to each exchange unit	Flow Conductivity	Indicator (0) Totalizer (E) Indicator (0)	1 to 4 At least 2 times volume between regeneration 1 to 2	Rate of flow through unit Start of regeneration cycle Start of regeneration cycle	Manual(E) Manual(E) Automatic(0) Manual(0)
Loss of Head	Pressure differential	Indicator (E)	1 to 3	Cleaning or replacement of bed material	Manual(E)
Regeneration	Level	Indicator (E)	Depth of Tank	Supply of regeneration	Manual(E)

Table 14 (Continued)
Metering, Instrumentation and Control Requirements
for Water Supply and Treatment

Location and Use	Type of Measurement	Type of Instrument Readout[(1)]	Range of Measurement and/or Readout	Controls	
				Item Regulated	**Type**
System	Flow	Indicator (E)	1 to 4	Rate of regeneration	Manual(E)
Aeration: Aerator Sump	Level	Indicator (E)	Depth of Sump	Influent flow	Manual(E) Automatic(0)
Disinfection & Fluoridation: Chlorine, hypochlorite, or fluoride solution	Flow Residual	Indicator (E) Indicator (E) Recorder (S)	1 to 10 1 to 10	Rate of application[2] Rate of application[2]	Manual(E) Proportional Automatic(0) Proportional Automatic(0)
Treatment Unit Effluent	Flow	Indicator (E) Totalizer (E) Recorder (0)	1 to 4		
Ozonation: Ozonized Air	Flow	Indicator (E)	1 to 10		Manual(E) Automatic(0)
Air and Water Operated Supply	Pressure	Indicator (E)	1 to 1.5 times shutoff pressure	Air and water feed	Manual(E)
Air Inlet and	Temperature	Indicator (E)	0 to 120		Manual(E)

Table 14 (Continued)
Metering, Instrumentation and Control Requirements
for Water Supply and Treatment

Location and Use	Type of Measurement	Type of Instrument Readout[(1)]	Range of Measurement and/or Readout	Controls	
				Item Regulated	Type
Outlet of Desiccators			degrees F		
Air leaving Desiccators	Humidity	Indicator (E)	0 to 100%	Humidity of air feed	Automatic(E)
Treated Effluent	Residual	Indicator (0) Recorder (S)	1 to 10	Rate of ozone application	Proportional Automatic(0)
Ozone Production	Voltage	Indicator (E)	0 to 100%		Manual(E) Automatic(0)
Clearwell: Influent Line	Flow	Indicator (0)	1 to 4	Postdisinfec-tion and fluoridation	Manual(E) Automatic(0)
Clearwell Basin	Level pH	Indicator (E) Recorder (0) Indicator (E) Recorder (0)	Depth of Basin 0 to 14 units	Raw water supply Chemical feed	Manual(E) Automatic(0) Manual(E) Automatic(0)
Distribution: Booster Pumps	Flow Pressure	Indicator (E) Recorder (0) Indicator (E)	1 to 4 0 to 1.5 times shutoff pressure	None Booster pumps	Automatic(E)

Table 14 (Continued)
Metering, Instrumentation and Control Requirements
for Water Supply and Treatment

Location and Use	**Type of Measurement**	**Type of Instrument Readout(1)**	**Range of Measurement and/or Readout**	**Controls**	
				Item Regulated	**Type**
Elevated Tank	Level or pressure Temperature	Indicator (E) Recorder (S) None	Depth of Tank 0 to 120 degrees F	Distribution pump Tank heater	Manual(E) Automatic(0[3] Automatic(E[4]
Service Connections	Flow	Totalizer (E)	Six months' flow volume	None	Automatic(E)
Miscellaneous: Wet Well for Pumps	Level	Indicator (0)	Depth of well	Pump on/off	Manual(E)
Raw water, filters, chemical dissolving tanks, atmosphere	Temperature	Indicator (0)	-40 to 120 degrees F	None	
Pump Discharge Lines	Pressure	Indicator (E)	0 to 1.5 times shutoff pressure	None	
Chlorine Storage and Feed Rooms	Weight Gas Conc.	Indicator (E) None	3 times full container weight	None Conc. alarm	Automatic(E)

Table 14 (Continued)
Metering, Instrumentation and Control Requirements
for Water Supply and Treatment

Location and Use	Type of Measurement	Type of Instrument Readout[(1)]	Range of Measurement and/or Readout	Controls	
				Item Regulated	Type

[1] Symbols
E= Essential. Items described are required wherever particular applications occur.
0= Optional. These items may be required (choice of designer)
S- Special Cases. This refers to items sometimes used in large installations. These are applied only when circumstances justify their use.
[2] Measurement device may be integral with feeder or controller.
[3] Use automatic if readout is unattended.
[4] For freezing climates only.

Table 15
Types of Measuring Devices Applicable to Water Treatment Plants

Primary Measurement and Type of Device	**Use Examples**	**General**	**Capacity**	**Range**
Open Channel Flow:		Accuracy is dependent on piping configuration. Consult vendor data on specific device.		
Flume (Parshall or Palmer-Bowlus)	Plant influent, bypass lines.	Suspended matter does not hinder operation. More costly than weir.	10 gal/min and up	75:1
Weir	Plant influent, plant effluent.	Requires free fall for discharge and greater headloss than flume. Influent weirs may plug.	0.5 gal/min and up	100:1 and up
Pressure Pipeline Flow: Differential Producers	Filled lines. Fluids under positive head at all times.	Impulse lines may clog if used with suspended matter. Consider automatic purging if device must be used in suspended matter.		
Venturi Tube or flow tube	Most fluid lines where solids build up and scale will not be a problem.	Long laying length required. Costly in large pipe sizes.	5 gal/min and up for liquid; 20 ft^3/min and up for gas	10:1

Table 15(Continued)
Types of Measuring Devices Applicable to Water Treatment Plants

Primary Measurement and Type of Device	**Use Examples**	**General**	**Capacity**	**Range**
Orifice Plate	Air and gasolines, water except filter effluent.	Clean fluids only. Headloss greater than flow tubes.	0.5 gal/min and up for liquid; 5 ft^3/min and up for gas	4:1
Flow Nozzle	Water except filter effluent.	Clean fluids only.	5 gal/min and up for liquid; 20 ft^3/min and up for gas	5:1
Average Pitot Tube	Water, air, gas.	Clean fluids only.	Determined by pipe sizes.	3:1
Displacement Meters	Plant water and distribution system service connections. Plant gasolines, sludge gasolines. Chemical addition lines.	Different types available. Maximum flow volume somewhat limited. May be in conjunction with chemical feed pump. Clean fluids only.	0.1 to 9,000 gal/min for liquid; 0 to 100,000 ft^3/min for gas	10:1
Sand Expansion: Float	Gravity filter.		Unlimited	20:1

Table 15(Continued)
Types of Measuring Devices Applicable to Water Treatment Plants

Primary Measurement and Type of Device	**Use Examples**	**General**	**Capacity**	**Range**
Weight: Scales	Chemical feed and storage equipment, sludge cake conveyor.	Weighing devices may be integral to gravimetric feeders.	1 to unlimited	12:1
Gas Concentration: Concentration indicator or alarm	Chlorine rooms.		0 to 100%	12:1
Time: Elapsed Time Meter (ETM)	Motors requiring periodic service, motors driving principal pumps.		0 to 10,000 hp	100,000:1
Revolutions: Counter	Positive displacement sludge pumps.	May be used for primary metering of sludge flow.	0 to 100 million	100M:1
Electric Power Use: Watt-hour meter	Plant power.	Public Utility may have governing requirements.	Unlimited	10,000:1
Differential Pressure	Batch and chemical tanks.	Specific gravity should be fairly constant. Build-up may be a problem.	Unlimited	20:1

Table 15(Continued)
Types of Measuring Devices Applicable to Water Treatment Plants

Primary Measurement and Type of Device	Use Examples	General	Capacity	Range
Bubble Tube	Water supply wells.	Requires air supply for automatic. Manual (hand pump type) available for indication only.	Depth limited by air pressure if automatic.	10:1
Pressure: Pressure Gauge	Pump discharge, transmission mains, elevated tanks.	Seals or diaphragms may be required to prevent corrosion or plugging of pressure impulse connections.	Vacuum to 1,500 lb/in^2g	10:1
Loss of Head Gauge	Gravity filters.		Unlimited	3:1
Temperatures: Thermometer or resistance thermal device	Plant influent, clear-well, atmosphere.		-80 to 1000 degrees F	10:1
Analytical Instruments: pH	Plant influent or effluent precipitator, neutralization, oxidation or reduction processes		0 to 14 units	

Table 15(Continued)
Types of Measuring Devices Applicable to Water Treatment Plants

Primary Measurement and Type of Device	**Use Examples**	**General**	**Capacity**	**Range**
Oxidation Reduction Potential (ORP)	Precipitator, oxidation or reduction processes.	May also be used for free residual chlorine.	-400mV to 400mV [1]	
Turbidity	Filter influent/effluent. Settling basing effluent.		0 to 1,000 NTU	
Residual Chlorine, Residual Ozone	Treatment unit effluent.		0 to 2 mg/L [1]	
Specific Ion Electrodes	Treatment unit effluent.		0 to 2 mg/L [1]	
1 - Depends on actual effluent requirements.				

Section 7: DISTRIBUTION AND TRANSMISSION

7.1 Distribution

7.1.1 System Planning. Basic data on design requirements for the distribution system are as follows: refer to AWWA Manual M32, Distribution Network Analysis for Water Utilities and AWWA Manual M31, Distribution System Requirements for Fire Protection, for additional detailed information.

7.1.1.1 Information Required. For planning distribution systems, secure the following information:

a) Topographic Map of Area Served. Secure all data on present and planned streets, elevations of ground level, and all control features of area.

b) Utilities. Secure data on sewers and drains, gas and petroleum oils and lubricants (POL) lines, steam lines, underground electric cables, and buried tactical and communication facilities.

c) Quantity Requirements. Secure gpm data at various points.

d) Pressure Requirements. Secure psi data at various points.

7.1.1.2 Design. Areas on high ground or with high pressure requirements should have a separate high service system. Provide for maintaining pressures with pumping, backed by elevated storage where possible. Mains should be designed for the maximum daily demand plus reserve capacity. Demand projections should be based on not less than 20 years in the future, with 50 years being preferable. Arterial mains should form a loop when possible.

a) Storage Reservoirs. Refer to Section 8 for reservoir criteria.

b) Valve System. Provide shutoff valves to sectionalize the system. According to Recommended Standards for Water Works, valves should be located at no more than 500 feet intervals in commercial districts and at not more than 800 foot intervals for other districts. Where systems serve widely scattered customers, and future development is not expected, the valve spacing should not exceed one mile.

(1) Lay out sections so that most of the design flow can be maintained if any one section is cut out of the system. Refer to MIL-HDBK- 1008C for fire flow requirements.

(2) Place valves in each branch at the point of connection to an arterial main.

(3) At intersections, valves should be provided at all branches.

c) Fire Hydrant Location. Refer to MIL-HDBK-1008C and Construction and Recommended Standards for Water Works, 1997 edition.

7.1.2 Size of Mains. Compute quantity requirements in accordance with Section 2.

7.1.2.1 Pressure Requirements Ashore

a) Flowing water pressure should not be less than 20 psi, higher pressures are required for ship berthing and drydock facilities in accordance with MIL-HDBK-1025 and MIL-HDBK-1029 series.

b) Residual pressure should meet the requirements of automatic fire extinguishing systems while providing 50 percent of the average domestic and industrial flows, and the fire flow. (Refer to MIL-HDBK-1008C.)

7.1.2.2 Computations. Analyze extensive systems using the Hardy-Cross method of successive approximations. Computer software such as $H_2$0NET, EPANET and Cybernet should be used.

7.1.3 Materials of Construction. Refer to AWWA manuals and standards for detailed information on pipeline material information. Listed below are AWWA manuals and standards for detailed information.

AWWA Manuals
M9 Concrete Pressure Pipe
M11 Steel Pipe - A Guide for Design and Installation
M23 PVC Pipe - Design and Installation

M27 External Corrosion
M41 Ductile Iron Pipe and Fittings
M45 Fiberglass Pipe Design

AWWA Standards

C104/A421.4	Cement Mortar Lining For Ductile-Iron Pipe and Fittings for Water
C151/A21.51	Ductile Iron Pipe, Centrifugally Cast, For Water
C200	Steel Water Pipe - 6 in. And Larger
C205	Cement-Mortar Protective Lining and Coating for Steel Water Pipes 4" and larger.
C210	Liquid-Epoxy Coating for the Interior and Exterior of Steel Water Pipelines.
C300	Reinforced Concrete Pressure Pipe, Steel-Cylinder Type
C301	Prestressed Concrete Pressured Pipe, Steel-Cylinder Type for Water and Other Liquids
C302	Reinforced Concrete Pressure Pipe, Non-cylinder Type
C304	Design of Prestressed Concrete Cylinder Pipe
C900	Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4 in. Through 12 in., for Water Distribution
C906	Polyethylene (PE) Pressure Pipe and Fittings, 4-in Through 63 in., for Water Distribution
C950	Fiberglass Pressure Pipe

7.1.3.1 Selection Factors. Consider the following factors:

a) Resistance to corrosion.

b) Strength against both internal and external loads.

c) Hydraulic characteristics.

d) Installation and field conditions.

e) Economic considerations.

f) Ease of maintenance.

g) Ease of making taps and connections.

7.1.3.2 Corrosion Protection. Refer to MIL-HDBK-1004/10, Electrical Engineering Cathodic Protection and AWWA M27, External Corrosion, for methods to be used in corrosion protection.

7.1.3.3 Maintenance of Low Friction. Refer to par. 7.2 for guidance on maintenance of low friction.

7.1.3.4 Structural Requirements. Refer to AWWA standards as stated in par. 7.1.3. for methods of determining and specifying pipe wall thickness for each pipe material and for other information pertaining to strength of pipe.

7.1.4 Installation. Recommended Standards For Water Works, Health Education Services, 1997 edition, provides information regarding installation requirements. The requirements consider the following factors:

a) Mains should be clear of all structures, adjacent to and parallel to streets, and where possible out of roadways.

b) Mains should be in an allocated higher part of street rights-of-way, to simplify separation from sewers and groundwater.

c) Mains should be laid in trenches separate from sewer lines, and above and at least 10 ft away from nearby sewers; preferably on the opposite side of the street.

d) Where a sanitary sewer crosses over a main, it must be in pressure pipe or encased in at least 8 in. of concrete for 10 ft on both sides. Provide a minimum vertical distance of 18 in. between the outside of the water main and the outside of the sewer.

e) Avoid laying mains in water or in trenches subject to flooding during construction.

f) Provide metallic tracer tape or wire over nonmetallic lines.

g) Pipes suspended above ground or on structural supports should be anchored to withstand thrust, seismic, wind velocities and other forces as specified in MIL-HDBK-1002 series dealing with loads.

7.1.5 Joints

7.1.5.1 Ductile Iron Pipe Joints. As specified in AWWA C110/A21.10, Ductile Iron and Gray-Iron Fittings, and AWWA C111/A21.11, Rubber Gasket joints for Ductile Iron Pressure Pipe and Fittings, with the following recommendations:

a) The push-on joint is recommended for general use.

b) The mechanical joint should be used in soft soils where settlement is anticipated, or where flexibility is required, for seismic design.

c) The ball joint may be used for river crossings and other installations requiring large joint deflections.

d) Flanged joints should be used where valves, fittings, and accessories are to be attached to pipes, in vaults, pits, and above ground locations where rigidity is required.

e) Sleeve-type mechanical couplings are useful where greater deflection is needed, where alignment problems may arise, and for connecting cast iron pipe to other pipe materials.

f) Clamp-type mechanical couplings are allowed as an optional jointing method to flanged joints except on pump suction lines; the pipe must be grooved or shouldered to accept this coupling.

g) Where the line must be maintained as an electrical conductor for cathodic protection use a cable bond conductor on both push-on-joints and mechanical joint pie. For electrical thawing use serrated silicon bronze wedges for push-on-joints.

7.1.5.2 Concrete Pipe Joints. Concrete pipe joints should be designed as specified in AWWA standards. The following AWWA standards are for concrete pipe:

C300	Reinforced Concrete Pressure Pipe, Steel-Cylinder Type
C301	Prestressed Concrete Pressure Pipe, Steel-Cylinder Type, for Water and Other Liquids
C302	Reinforced Concrete Pressure Pipe, Non-Cylinder Type
C303	Concrete Pressure Pipe, Bar-Wrapped, Steel-Cylinder Type

7.1.5.3 Steel Pipe Joints. Steel pipe joints should be selected as specified in the following AWWA standards:

C200	Steel Water Pipe - 6 in. and Larger
C206	Field Welding of Steel Water Pipe
C207	Steel Pipe Flanges for Waterworks Service - Sizes 4 in. Through 144 in.
C219	Bolted, Sleeve-Type Couplings for Plain-End Pipe
C221	Fabricated Steel Mechanical Slip-Type Expansion Joints

AWWA C200 provides general information regarding pipe joints.

a) Rubber-gasketed joints and sleeve-type mechanical couplings are recommended for general use. The couplings are useful for the same purposes as listed for cast iron pipe.

b) Welded joints may be used on pipes which have no inside coating and for pipes with inside diameter greater than 24 in. with inside coating, where the inside is accessible and the joints are lined after welding.

c) Flanged joints and clamp-type mechanical couplings. Same as for cast iron pipe.

d) Expansion joints of the stuffing box type should be used at appropriate intervals on pipe with welded joints to relieve strains, especially for exposed pipe.

e) Where a line must be maintained as an electrical conductor for cathodic protection, use bonding cables and lugs.

7.1.5.4 Polyvinyl Chloride (PVC) Joints. PVC joints should be selected as specified in AWWA C905, Polyvinyl Chloride (PVC) Water Transmission Pipe and Fabricated Fittings, 14 in. Through 36 in. For Water Transmission and Distribution and AWWA C907, Polyvinyl Chloride (PVC) Pressure Fittings for Water 4 in. Through 8 in.

7.1.5.5 FRP-TR Joints. AWWA C950 standards should be followed in selecting FRP-TR Joints.

7.1.5.6 Polyethylene Joints. AWWA C906 standards should be followed.

7.1.6 Trenches, Backfill, Anchors, and Supports. Follow AWWA C600, Installation of Ductile-Iron Water Mains and Their Appurtenances, or AWWA C605, Underground Installation of Polyvinyl Chloride (PVC) Pressure Pipe, when considering trenches, backfill anchors, and supports.

7.1.6.1 Trench Conditions. Trench bottoms in stiff material should be cut 6 in. below pipe inverts for nominal pipe sizes 24 in. or smaller and 9 in. below pipe inverts for nominal pipe sizes 30 in. and larger to provide proper bedding. (Refer to AWWA C600 and AWWA C605.)

7.1.6.2 Bedding. No pipe should rest directly on rocks or boulders. Except as provided in the following statement, all pipes should be uniformly supported throughout their lengths on a compacted base using firm trench soil or granular materials. Full-length crushed stone or gravel bedding may support the pipe where soils are soft and set. Where the ground has inadequate bearing value, provide pipe supports and stringers. Bedding material or a select backfill material should be installed from the spring line of the pipe to a minimum of 6 in. over the pipe.

7.1.6.3 Supports. Exposed pipe should be supported either on saddles or by hangers. Supports should be spaced to limit deflection of steel pipe to a maximum of 1/360 of the span, and to prevent over stressing any joints.

7.1.6.4 Anchorage. Anchorages should also be provided as required to accommodate expansion due to temperature rise.

Anchorages should be provided for buried or exposed pipe at all bends, as required to resist vertical or horizontal thrust. Refer to AWWA C600, Installation of Ductile-Iron Water Mains and Their Appurtenances; and AWWA C605, Underground Installation of Polyvinyl Chloride (PVC) Pressure Pipe Fittings for Water for standard blocking.

7.1.7 Railroad Crossings. Mains to be laid near railroads should be designed to withstand the dynamic loads and vibrations caused by trains. Place the mains in a larger sized conduit, to reduce the vibration effects of moving trains. Refer to American Railway Engineering Association (AREA), Manual for Railway Engineering, Volumes I and II.

7.1.8 Stream Crossings. Wherever possible, underwater mains should be buried in the stream beds for protection against freezing and disturbance by currents, ice, floating debris, ship anchors, and dredging. Consider multiple crossings when a high degree of reliability is required. The following conditions are recommended:

a) All joints should be watertight. Use flexible ball joints with rigid pipe materials or flexible plastic pipe.

b) Provide shutoff valves at each end, so that the mains may be isolated during testing and repairing.

c) Provide flushing facilities.

d) Because of inaccessibility, make special provision for corrosion control.

7.1.9 Valves. Refer to pars. 7.2 and 7.4 which recommend air, vacuum, and blowoff valves to be used. Make any necessary provision to release trapped air, break vacuums, and permit main flushing.

7.1.10 Testing. Refer to AWWA Standards C600 series, for testing requirements for each type of pipe material. For disinfection testing requirements refer to AWWA C651, Disinfecting Water Mains.

7.2 Transmission

7.2.1 Location of Transmission Line. Transmission lines convey water from the source to the treatment plant or to the distribution system. This water may be treated or untreated, depending on the location of the treatment plant. Routes should be selected, consistent with economic considerations, to meet the following desirable characteristics:

a) It should use a gravity line, if head is available.

b) It should be the shortest route from the point of intake to point of delivery.

c) It should bypass rough or extremely difficult terrain and be accessible for construction and repairs.

d) It should be below the hydraulic grade line but as close to it as practicable.

e) It should avoid dangers of landslides and flood waters.

7.2.2 Types. In designing transmission lines, note the following:

a) Avoid pumping if feasible, and thus reduce pressures on the line, as well as costs.

b) Pumping facilities may sometimes be planned for a transmission storage location rather than at the source.

7.2.2.1 Pipelines. Gravity or pressure pipelines should be used for transmission except when special circumstances justify the use of aqueducts or tunnels.

7.2.2.2 Aqueducts. Aqueducts or canals under no pressure, may be used to convey large flows when the construction is economically justified. They are used only for very large works or under special circumstances.

7.2.2.3 Tunnels. A tunnel of the gravity or pressure type should be used to convey water underground, under either of the following conditions:

a) Where there is no other alternative route.

b) Where its construction is economically justified.

7.2.3 Capacity. Provide sufficient transmission line capacity to meet the following requirements.

a) Permanent Installation.

(1) Domestic and General Uses. Plan for the maximum daily demand plus reserve capacity for the estimated load not less than 20 years in the future, unless this growth factor has already been used in computing the maximum daily demand. Evaluate effect of long detention time on decay of chlorine residual.

(2) Essential to Defense. The basis of design should be the maximum daily demand plus reserve capacity for the estimated load 20 to 40 years in the future.

b) Temporary Installations. Use the maximum daily demand plus a reasonable reserve capacity for the expected life of the installation.

7.2.3.1 Design Velocity. Velocities above 5 ft per second should not be used because of high friction losses. Where excess head is available, limit the velocities as follows:

TYPE OF STRUCTURE	MAXIMUM VELOCITY (fps)
Unlined tunnels	12
Pipe:	
Cement-lined concrete	15
Steel and ductile iron	15

7.2.3.2 Size. Determine the hydraulic details from cost studies. Allowance should be provided for the loss of carrying capacity during the expected service life.

7.2.3.3 Arrangements. Where there is only one major source of supply, and little or no transmission storage, multiple conduits should be provided, whenever possible, so that delivery of water need not be interrupted during repairs. If feasible, the conduits should be arranged to enter the Military activity from opposite directions.

7.2.4 Materials of Construction. Refer to paragraph 7.1.3.

7.2.4.1 Selection Factors. Consider the following factors.

a) Resistance to corrosion

b) Strength against both internal and external loads

c) Hydraulic characteristics

d) Installation and field conditions

e) Economic considerations

7.2.4.2 Tunnels. A thorough geologic investigation should be undertaken in the design stage of a rock tunnel. It should be lined if needed to attain carrying capacity. Grout the rock seams as needed to reduce or prevent leakage. Expert guidance should be sought in the design and construction.

7.2.4.3 Corrosion Protection. Provide adequate internal and external protection to ensure the necessary life of the line (refer to par. 7.3).

7.2.4.4 Preserving Low Hydraulic Friction. The following factors tend to lower the hydraulic efficiency:

a) Tuberculation. Pipes subjected to tuberculation should be provided with protective lining.

b) Slime Formation. Provide control of slime by chemical treatment at the intake of the line. If attributable to manganese or iron, provide for removing these substances before the water is transmitted.

c) Encrustations. Provide for adjusting the chemical stability of the water as required to prevent excessive deposition in the line.

7.2.4.5 Structural Requirements. Refer to par. 7.1 for structural criteria. All steel pipe should be designed in accordance with AWWA Standard C200, Steel Water Pipe - 6 in. and Larger.

7.2.5 Pipe Installation. Except in special cases, all pipes should be buried with a minimum cover of 2.5 ft. Where frost penetration exceeds 2.5 ft, as indicated on National Weather Service charts, the depth of cover should be increased to 6 in. below the maximum recorded depth of frost penetration based on local records in the area of installation. See Figure 1 for generalized frost information.

7.2.5.1 Exposed Pipe. Exposed pipe may be placed on bridges or piers for crossing streams or ravines. Exposed nonmetallic pipe may be used only in climates not subject to freezing. Exposed cast iron or steel pipe subjected to freezing should be insulated or protected.

7.2.5.2 Inspection. All large conduits should be accessible for internal inspection.

a) Joints. Refer to par. 7.1 for recommended joints.

b) Trenches, Backfill, Anchors, and Supports. Refer to par. 7.1 for criteria related to trenches, backfill, anchors, and supports.

c) Railroad Crossings. Refer to par. 7.1 for criteria for railroad crossings.

d) River Crossings. Refer to par. 7.1 for criteria for river crossings.

e) Valves. Refer to par. 7.4 for detailed information on valve types, applications and characteristics. The following paragraphs pertain to transmission line valves.

(1) Provide air release valves as required based on an analysis of the system. For flexible pipe which might collapse under a vacuum, place vacuum valves as necessary, based on an analysis of the system; also adjacent to each shutoff valve on the downstream side. An active building service connection at a summit may serve as an air release valve.

(2) Provide a blowoff at each depression for draining the pipe. The minimum size of blowoff valves should be 2 in. for every foot of diameter of the pipeline.

(3) Shutoff valves should be installed at reasonable locations to allow isolation of any particular section during repair and testing. The spacing should not exceed 5,000 ft on long lines and 1,500 ft on loops.

(4) Check any danger of water hammer on long lines, and provide special valving to reduce it. Refer to par. 5.4.8 for further information regarding surge prevention.

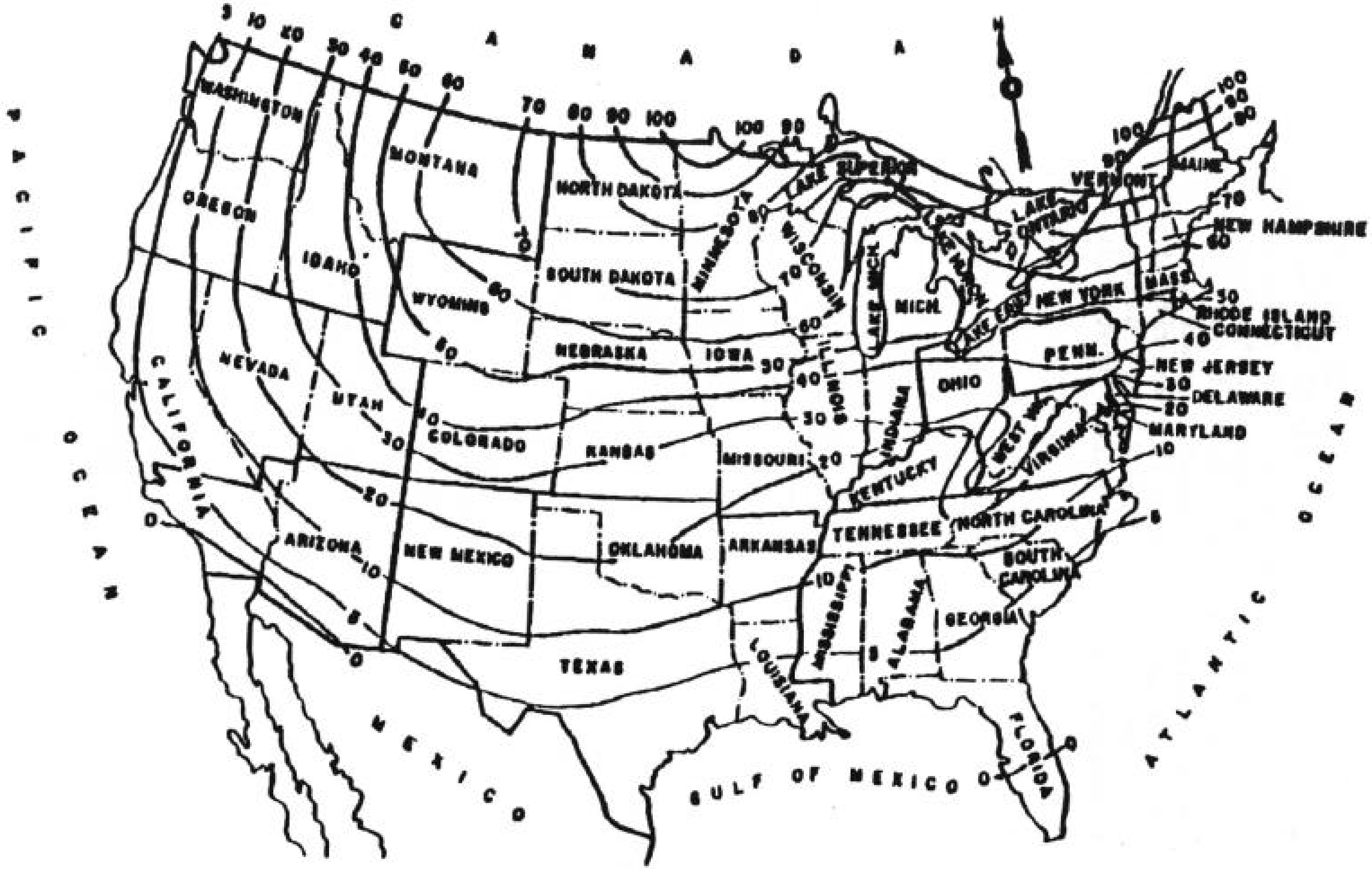

Figure 1
Extreme Frost Penetration

7.2.6 Testing. All new or repair pipes should undergo a hydrostatic pressure test before being put into service. Each pressure section should be isolated and pressure tested according to AWWA C600, Installation of Ductile-Iron Water Mains and Their Appurtenances. Each gravity and pressure section should be tested for leakage. Leakage should not exceed rates specified in AWWA standard for pipe material being tested.

7.2.7 Disinfection. Refer to AWWA C651, Disinfecting Water Mains for criteria.

7.3 Corrosion Protection. Refer to AWWA Manual M27, External Corrosion - Introduction to Chemistry and Control, for corrosion protection and MIL-HDBK-1004/10, Electrical Engineering Cathodic Protection.

7.3.1 Methods of Protection. Using corrosion resistant material, bolts and connectors subject to corrosion should be more resistant in composition than the main piping metal. Install dielectric fittings between ferrous mains and cuprous building services.

7.3.2 Treatment of Water. Refer to Section 6 for acceptable methods of treatment.

7.4 Valves and Hydrants

7.4.1 Valves. See Table 16 for the availability of types of valves and their applications.

7.4.1.1 General Purpose Valves

a) Gate Valves. Refer to the criteria for control valves for distribution systems in MIL-HDBK-1008C and AWWA Manual M44, Distribution Valves: Selection, Installation, Field Testing, and Maintenance. Use valves conforming to AWWA Standard C500, Metal-Seated Gate Valves for Water Supply Service; AWWA Standard C509, Resilient-Seated Gate Valves for Water Supply Service.

b) Butterfly Valves. Use the same criteria as was recommended for gate valves; also use AWWA Standard C504, Rubber-Seated Butterfly Valves.

c) Sluice Gates. Use AWWA Standard C501, Sluice Gates, for guidance on sluice gates.

7.4.1.2 Special Purpose Valves. Consult manufacturers for capacities and construction of the various types, to be used as follows:

a) Air Valves. Use air valves to release any air collecting at high points in filling lines.

b) Altitude Valves. Use altitude valves for supply lines to elevated tanks or reservoirs. These valves are actuated by the water level in the tanks or reservoirs, to close when the tank is full and open when the level on the system pressure lowers. Also refer to MIL-HDBK-1008C.

c) Float Valves. Use float valves on supply lines to fill tanks or reservoirs and maintain their water levels.

d) Plug Valves. Use for control of pumping rates at low volume.

e) Pressure Regulating Valves. Use pressure regulating valves to deliver water from a high to a low pressure system wherever the pressure downstream drops below a preset value. In addition, these valves can be fitted to open when upstream pressure drops below downstream pressure. Pressure regulating valves on water distribution system should be located in accordance with MIL-HDBK-1008C.

f) Pressure Relief Valves. Use pressure relief valves to relieve any pressure in tanks or pipelines above a preset value.

g) Vacuum Valves. Use vacuum valves to admit air into tanks or pipelines for relieving vacuums induced by a break or a rapid opening of valves.

7.4.2 Hydrants. Refer to criteria for hydrants for distribution systems in MIL-HDBK-1008C and AWWA Manual M17, Installation, Field Testing, and Maintenance of Fire Hydrants. Use hydrants conforming to AWWA Standard C502, Dry-Barrel Fire Hydrants; or to Underwriters Laboratories’ Standard UL 246, Hydrants for Fire Protection Services.

7.4.2.1 Installation. Follow installation requirements in MIL HDBK-1008C and AWWA Manual M17, Installation, Field Testing, and Maintenance of Fire Hydrants.

7.4.2.2 Valve. A shutoff valve with a valve box should be installed on the branch between the hydrant and the main. Wherever possible, provide a concrete collar around the branch between the valve and the hydrant, to protect the valve in case the hydrant receives impact damage. The branch line to the hydrant and the valve should be 6-in. diameter.

7.4.3 Appurtenances. Criteria regarding selection of appurtenances are given below:

7.4.3.1 Operator Shutoff Valves and Gates. Use manual, direct, and geared type on all shutoff valves and gates for normal operations. Use automatic type, either motorized, hydraulic, or pneumatic, above grade or housed, in the following applications:

a) Where the gates or shutoff valves are too large for manual operation.

b) Where a specific rate is set for opening or closing, to reduce surges in pipelines.

c) Where frequent operation is required (medium sized valves).

d) Where required at large multi-pump installations.

e) Where their installation is justified both economically and functionally.

7.4.3.2 Valve Boxes. Use valve boxes for small and medium sized underground shutoff valves.

Table 16
Application of Valves

Type	Application	Remarks
Check Valves		
Swing checks	All horizontal applications	Refer to AWWA C508.
Ball checks	On reciprocating pumps	Small diameter.
Vertical checks	All vertical applications	Refer to AWWA C507.
Cone checks	Surge relief	Requires automatic operator.
Cushioned checks	Surge relief	Slow closing
Foot valves	Prevents loss of prime in suction lines	-
Flap valves	At pipe outlets	-
Shutoff Valves		
Gate valves[1]	All applications	Refer to AWWA C500 and/or AWWA C509.
Butterfly valves	All applications	Largest size over 72 in. Refer to AWWA C504.

Table 16 (Continued)
Application of Valves

Type	**Application**	**Remarks**
Plug valves, eccentric	All applications	Suitable for water containing solids and for three-way valves.
Globe valves	All applications	Small diameter
Needle valves	All applications	Small diameter
Hydraulic needle valves	Reservoir outlets	Very large size requiring hydraulic operators
Mud valves	Bottom drain opening of basins	-
Gates		
Radial gates	Channel and reservoir outlets	-
Slide gates	Channel and reservoir outlets	Low heads
Sluice gates	Wall openings	Refer to AWWA C501.
Shear gates	Wall openings (low head)	Size up to 24 in.
[1]Except for low pressure, service gate valves 16-20 in., and larger should be equipped with bypass. Refer to AWWA C500 and/or AWWA C509.		

7.4.3.3 Valve Vaults or Manholes. Use vaults or manholes for large shutoff valves on transmission lines, on arterial mains of distribution systems, and where accessibility for servicing is required.

7.5 Cross Connections and Backflow Prevention With Non-potable Supplies. Refer to AWWA Manual M14, Recommended Practice for Backflow Prevention and Cross-Connection Control. For Air Force projects use AFI 32-1066.

7.5.1 Backflow. Backflow of waste or contaminated water into the distribution system due to back-siphonage or backpressure should be prevented.

7.5.1.1 Sources. Conditions under which backflow can occur are given below. Such conditions should not be permitted.

a) Improper plumbing designs.

b) Direct connections with nonpotable supplies.

(1) Improper pipeline interconnections.

(2) Potable supply lines submerged in nonpotable water.

(3) Direct connections of drains from sources such as a fire hydrant or valve box to a storm or sanitary sewer.

(4) Improper connections by users.

c) Improperly designed or constructed distribution systems. These are systems within an area subject to flooding or systems that may be too close to subsurface sources of contamination, such as septic tanks, drain fields, sewers, and cesspools. Any leakage combined with lower pressure in the distribution system can cause backsiphonage.

d) A backflow preventer installed in a location subject to submergence.

7.5.1.2 Protection Against Contamination

a) Design for the absolute minimum number of interconnections.

b) Provide siphon breakers in all plumbing systems.

c) Provide positive separations (air gaps) between potable water lines and any units containing contaminated water, such as hospital sterilizers, washing machines, and tanks of dangerous liquids.

d) Provide backflow-preventing devices at all interconnections with nonpotable water lines that cannot be eliminated or protected by an air gap.

e) Provide backflow-preventing devices on irrigation systems, refer to par. 7.7.

7.5.2 Backflow Preventers. Where it would be extremely difficult to provide an air gap between two systems, and where back pressures are possible, a reduced pressure principle backflow preventer can be used. In lieu of air gaps, only reduced pressure principal backflow preventers are acceptable. Follow recommendations of the Manual of Cross-Connection Control of the Foundation for Cross-Connection Control and Hydraulic Research, University of Southern California, the criteria of NAVFACINST 11330.11D, Backflow Preventers, Reduced Pressure Principle Type AFI 32-1066 and, AWWA Manual M14, Recommended Practice for Backflow Prevention and Cross-Connection Control.

7.5.3 Air Gaps. Use an air gap (between a supply pipe and receiving vessel) whenever possible on any potable water line discharging to any place where contamination could occur. An air gap removes the physical link to a potential contamination source, and is preferred over backflow prevention devices, which are subject to failure. When installed, the air gap should be at least twice the diameter of the supply pipe, but in no case less than 6 in.

7.6 Service Connections

7.6.1 Piping. See Table 17 and AWWA Standard C800, Underground Service Line Valves and Fittings, for piping materials allowed and the advantages and disadvantages of these materials.

7.6.1.1 Selection Factors. Consider the following factors in selecting service piping:

a) Durability.

b) Type of water.

c) Availability.

d) Ease of installation and maintenance.

e) Economic considerations.

7.6.1.2 Structural Requirements. Refer to AWWA Standard C800, Underground Service Line Valves and Fittings, on structural requirements.

7.6.2 Appurtenances. Refer to AWWA Standard C800, Underground Service Line Valves and Fittings for requirements concerning appurtenances.

7.6.2.1 Corporation Stops or Cocks. Install these stops at all connections less than 2-in. diameter to water mains. Use tapping saddles and valves for larger connections.

7.6.2.2 Curb Stops or Cocks. Install curb stops, with valve boxes, at the street line to shut off service lines. Where lines may need draining, use the stop-and-waste type.

7.6.2.3 Goosenecks. Use a flexible gooseneck to connect nonflexible service pipe to main.

7.6.2.4 Service Meters. Refer to AWWA Manual M6, Water Meters - Selection, Installation, Testing, and Maintenance. For warm climate, install in a covered meter box away from traffic. For cold climate, install indoors or in a frost proof enclosure. Types as follows:

a) Displacement. Use this type when the minimum flow is below 12 gpm. Use a meter yoke for 1-in. and smaller meters.

b) Compound. These meters are used where flow ranges exceeding 10 to 1 are to be measured.

c) Propeller Type (Velocity). Use this type to measure large flows where only a small loss of head is allowed.

d) Fire Flow Meter. Fire flow meters should be used in lines carrying water for fire protection.

Table 17
Service Pipe Materials[3]

Material	Sizes Available	Advantages	Disadvantages
Brass	All standard sizes	Corrosion resistant. Good hydraulic characteristics.	Nonflexible.[1] Not suitable for soft water with high CO_2 content. Not suitable in presence of seawater.
Copper (pipe)	All standard sizes	Corrosion resistant. Good hydraulic characteristics.	Nonflexible.[1] Not suitable for soft water with high CO_2 content.
Copper (tubing)	All standard sizes	Corrosion resistant. Flexible in small sizes. Ease of installation. Good hydraulic characteristics.	Not suitable for soft water with high CO_2 content.
Ductile Iron	3 in. And larger	Corrosion resistant.[2] Good hydraulic characteristics.[2] Strong and suitable for large service lines.	Nonflexible.[1]

Table 17 (Continued)
Service Pipe Materials[3]

Material	Sizes Available	Advantages	Disadvantages
Galvanized Steel	All standard sizes	Less expensive.	Nonflexible.[1] Low corrosion resistance.
Polyethylene	All standard sizes	Long laying lengths Lightweight High Impact Strength	Special tooling required for fusing joints. Subject to surface change effected by long term ultra-violet exposure. Subject to attack by organic solvents or petroleum
Polyvinyl chloride (PVC)[4] ABS plastic pipe and fiber-glass reinforced plastic pipe	All standard sizes	Corrosion resistant. Less expensive. Ease of installation. Good hydraulic characteristics. Lightweight.	Cannot be thawed electrically. Life expectancy may be reduced by constant exposure to sunlight. Exposed pipe requires support. Nonflexible.[1] Selected bedding may be

Table 17 (Continued) Service Pipe Materials[3]			
			required.

[1]Non flexible pipe requires a flexible gooseneck at the connection to main.
[2]When cement-mortar lined as required by AWWA C104.
[3]Safe Drinking Water Act, Pub. L.93-533 as amended 1986.
[4]When PVC is in compliance with 40 CFR Part 141.50.

7.6.2.5 Stop-and-Waste Valve. Install this unit at the end of service lines just inside the building wall.

7.6.2.6 Seismic Zones. Provide an earthquake valve in a pit on water service lines to buildings as called for in US Army TI-809-04, Triservice Engineering Manual for Seismic Design of Buildings.

7.6.3 Installations. Refer to AWWA Standard C800, Underground Service Line Valves and Fittings, and AWWA Manual M6, Water Meters - Selection, Installation, Testing, and Maintenance, for installation requirements. All connections should be at least 10 ft away from any subsurface source contamination.

7.7 Irrigation Systems. Irrigation systems should be designed using accepted commercial standards for the region where the system will be constructed.

7.7.1 Sanitary Protection. To protect a potable system from contamination by an irrigation system, comply with the following criteria.

7.7.1.1 Backflow Prevention. Provide a pressure type vacuum breaker or a reduced pressure type backflow preventer at each point where an underground sprinkler system is connected to a potable water supply. A pressure type vacuum breaker is adequate when it is located aboveground, higher than the highest sprinkler head and its elevation is above that which may be flooded. Otherwise a reduced pressure backflow preventer is required. Delete this requirement when the system is connected to a nonpotable water supply system.

7.7.1.2 Buried Sprinklers. Sprinkler heads buried in the ground and flush type heads are prohibited, except where a separate nonpotable water system is being used.

7.7.1.3 Sprinklers With Risers. Fixed or automatic "pop up" risers are permitted.

7.8 Meter Vaults and Boxes

7.8.1 Meter Vaults. Vaults should be easily accessible but away from normal traffic.

7.8.1.1 Construction. Where necessary, watertight structures should be used.

a) Small Vaults. Use concrete blocks, brick, or reinforced concrete structures.

b) Large Vaults. Use reinforced concrete structures.

7.8.1.2 Access. Vaults should be locked where necessary to protect against unauthorized intrusion.

7.8.2 Boxes. Wherever possible, place meter boxes away from normal traffic.

7.8.2.1 Construction Boxes. Construction boxes may be made of sections of clay or concrete pipe, or precast concrete or cast iron.

7.8.2.2 Covers. Box covers should be cast iron or aluminum with a locking device.

7.8.2.3 Combinations. In nonfreezing climates, it is permissible to use aboveground cast iron combination meter boxes and meter yokes.

Section 8: STORAGE

8.1 Function

8.1.1 General. Wherever feasible, design storage to provide flow through circulation, with compartments.

8.1.2 Purpose. Storage reservoirs serve the following purposes:

a) To allow a balanced flow through pipelines between the source and the treatment plant or distribution system.

b) To supply water during peak demand periods.

c) To maintain pressure in the distribution system.

d) To supply water during power outage or repair of pumps.

e) To provide an emergency supply for fire protection.

8.1.3 Site Considerations

a) Hydraulic analysis should be used to determine the best storage reservoir locations for each system to ensure flow, pressure & water quality.

b) In medium and large distribution systems, storage reservoirs are generally located near centers of heavy demand.

8.2 Types of Storage

8.2.1 Ground Storage Tanks. Use these tanks where the topography permits in lieu of the more expensive elevated tanks, or where required by the following conditions:

8.2.1.1 Size Limitation. Where requirements are very large and costs of elevated storage run unusually high, part of the distribution storage may be provided as ground-level storage.

8.2.1.2 Height Limitation. Where the height of elevated tanks required by the operating pressure becomes an aviation hazard, use ground storage tanks.

8.2.1.3 Transmission Line Storage. Use ground storage in conjunction with long transmission lines, to aid in meeting peak demands.

8.2.2 Elevated Tanks. Use elevated tanks to store water at the elevation required to maintain proper operating pressure and to allow gravity discharge from the tank into the distribution system. Standard capacities for welded steel tanks are given in AWWA Standard D100, Welded Steel Tanks for Water Storage. In most cases the cost of elevated tanks limits their maximum practical size to between 1 and 2 million gallons.

8.2.3 Underground Storage Tanks. Use this type of storage as required by the following conditions:

a) Where economy of construction results.

b) Where protection against freezing is required.

c) Where the area above the ground is to be utilized otherwise.

d) Where the hydraulic grade at a tank site requires the tank to be below grade.

e) Where protection against sabotage and destruction warrant concealment.

8.2.4 Hydropneumatic Tanks. Use Hydro pneumatic tanks at small activities where the demand is not enough to justify any other type of storage. Protect the tank from freezing. Design the tank to meet pressure vessel requirements. Provide air compressors, safety valve, and sight glass, to show the air:water ratio.

8.3 Materials and Construction

8.3.1 Materials. For available material and their characteristics, see Table 18.

8.3.1.1 Selection. Consider the following factors affecting material selection:

a) Life expectancy

b) Capacity and head requirements

c) Availability

d) Economic considerations

e) Water characteristics

f) Environmental conditions

8.3.2 Construction. Construction of the principal types of storage tanks is as follows:

8.3.2.1 Aboveground Storage Tanks

a) Piping Arrangement. For large tanks, place inlet and outlet pipes at opposite ends or sides, to provide circulation with the outlet pipe near the bottom. Otherwise, provide baffles in the tank.

(1) Provide overflow and drain pipes discharging to storm drains, but provide air gap to prevent contamination.

(2) Place valves on all pipes except overflow pipes.

(3) Install all valves so that they will stand out of groundwater or runoff, to prevent possible contamination, and to be easily accessible to operating personnel.

b) Depth. The total water depth should be a minimum of 12 ft to avoid the growth of organisms due to temperature and the reduction of capacity due to ice.

Table 18
Storage Tank Materials

Materials	**Type of Tank**	**Maximum Capacity (gal)**	**Advantages**	**Disadvantages**
Concrete	Ground storage tank Standpipes Underground storage tanks	Unlimited 1,000,000 Unlimited	Large Volume. Lower Maintenance cost than steel Adaptability to architectural treatment. Ease in burying underground.	Low head; do not exceed 50 ft. Greater Weight. Higher first cost than steel. Less watertight than steel unless prestressed or lined.
Steel	Elevated storage tanks Ground storage tanks Standpipes	3,000,000 10,000,000 3,000,000	Adaptability to high heads. Ease of erection. Lower first cost than concrete. Stores water under pressure. Lighter in weight than concrete.	Higher maintenance and protection cost than concrete. Require protection against freezing. High cost per unit stored.

Table 18
Storage Tank Materials

Materials	Type of Tank	Maximum Capacity (gal)	Advantages	Disadvantages
			Leaks easily repaired.	
Fabric	Ground storage	20,000	Low cost. Ease of erection. Portable	Not watertight Small volume. Short life.
Composite	Elevated storage tanks (concrete column, steel bowl)	3,000,000	Less maintenance cost than all steel elevated tanks. Multi-use capabilities.	More difficult to remove/demolish than all steel.

c) Appurtenances. Include the following appurtenances:

(1) Outside tank ladder.

(2) Roof hatch with lock.

(3) Screened vent.

(4) Flanged access hole near the ground.

(5) Water level indicator and alarm.

(6) Sampling access points.

d) Structural Design. For criteria on structural design of reinforced concrete and prestressed concrete, refer to NAVFAC DM-2.04, Concrete Structures. Steel tanks should meet AWWA Standard D100. Wire and Strand-Wound, Circular, Prestressed Concrete Water Tanks should meet AWWA Standard D110. Circular Prestressed Concrete Water Tanks With Circumferential Tendons should meet AWWA Standard D115.

e) Dual Tanks. When storage for a station or area is provided by ground storage only, consideration should be given to the provision of two tanks to maintain partial capacity during repairs or cleaning of one tank.

8.3.2.2 Underground Storage Tanks. Requirements for the design of underground storage tanks are given below:

a) Piping Arrangements. Follow the criteria given for ground storage tanks.

b) Depth. Design for a minimum depth of 8 ft

c) Insulation. Cover the waterproofed roof with a minimum of 2 to 3 ft of earth, planted with grass, graded, and drained to prevent ponding of surface water.

d) Compartments. Divide large tanks into several compartments, to minimize the loss of storage capacity during repair of any one section.

e) Appurtenances. Provide the following appurtenances:

(1) Access and valve chambers with their tops 6 in. above grade.

(2) Inside ladders or manhole steps.

(3) A screened vent above ground.

(4) Water level indicators and alarms.

(5) Sampling access points.

f) Structural Design. For design criteria of concrete underground structures, refer to NAVFAC DM-7.02, Foundations and Earth Structures, and MIL-HDBK-1002, Structural series.

8.3.2.3 Standpipes. The design of standpipes should be based on the criteria given below.

a) Useful Storage Capacity. Locate the standpipes on high ground, to obtain maximum usable storage volume above the required static head.

b) Height. Determine the necessary height from the following considerations.

(1) Capacity required.

(2) Head needed to develop the required distribution pressure.

(3) Limitation for aviation clearance set by military or civilian authorities.

(4) Structural stability.

(5) Watertightness for concrete standpipes. A special membrane is required for those subjected to heads in excess of 50 ft

(6) Economic considerations.

c) Piping Arrangements. Use a single riser pipe as both inlet and outlet.

(1) Provide an overflow and drains. Drains should not be connected directly to sewers.

(2) Place valves on all pipes except the overflow.

d) Appurtenances. Provide the following appurtenances:

(1) Ladders on the outside of the tank and on the roof.

(2) A roof hatch with lock.

(3) Screened vent, altitude valve, and overflow.

(4) Water level indicators and alarms.

(5) Bottom access manholes.

(6) Sampling access points.

e) Structural Design. Criteria for the design of reinforced concrete and prestressed concrete standpipes are given in NAVFAC DM-2.04. For steel standpipes, use AWWA Standard D100.

8.3.2.4 Elevated Storage Tanks. Design elevated storage tanks in accordance with the criteria given below.

a) Height. Use the same criteria given for standpipes.

b) Piping Arrangements. Use the same criteria given for standpipes.

c) Appurtenances. Provide the following appurtenances:

(1) Tower, outside tank, and roof ladders.

(2) A roof hatch with lock.

(3) A screened vent, an altitude valve, and an overflow.

(4) A water level indicator and alarm.

(5) A valve vault.

(6) Heating equipment for freezing climates.

(7) Sampling access points.

d) Structural Design. For criteria on structural design, use AWWA Standard D100 for steel elevated tanks.

e) Location. Adequate clearance should be provided between the exposed steel of elevated tank legs and buildings, structures, or open storage of any flammable materials. Otherwise, fireproofing of legs is required. Refer to NFPA Standard No. 22, Water Tanks for Private Fire Protection, for details.

8.3.2.5 Hydropneumatic Tanks. For design criteria, refer to booster system in MIL-HDBK-1003 series.

8.4 Protection

8.4.1 Freezing. In areas where frost penetration exceeds 30 in. (see Figure 1) protect storage tanks against freezing.

8.4.1.1 External Insulation. Cover all exposed piping (including risers to elevated storage tanks) with adequate insulation.

8.4.1.2 Heating Equipment. Special considerations for heating equipment in locations where freezing can occur are given below.

a) Aboveground and Elevated Tanks and Standpipes. In locations where freezing can occur, heat should be provided in accordance with the provisions of NFPA Standard No. 22. The method of heating should be selected on the basis of economy of installation and operation for the particular location involved.

b) Exposed Piping and Valves. Provide electric heating elements inside a small enclosure covering these parts.

8.4.1.3 Altitude Valves. Provide an altitude valve that can, in winter, be set to keep the high water level at minimum of 3 ft below the overflow, thus preventing floating ice from damaging the tank roof when lifted by rising water.

8.4.2 Corrosion Protection. Refer to MIL-HDBK-1004/10, Electrical Engineering Cathodic Protection and AWWA D102, Coating Steel water-Storage Tanks.

8.4.3 Pollution. Protection against pollution should be accomplished as discussed below.

8.4.3.1 Roof. Cover all tanks and reservoirs with roofs to prevent contamination from the atmosphere. Lumber treated for preservation may contain arsenic or other toxic chemicals.

8.4.3.2 Ground. To divert the surface runoff, grade and drain around ground storage and underground storage tanks.

8.4.3.3 Vents. To keep out insects and rodents, provide 20-mesh bronze insect screens over all vent openings. The vents should be rainproofed by using Goose necks or vent caps.

8.4.3.4 Underground Storage Tanks. These tanks should have watertight joints to avoid contamination from subsurface sources.

8.4.3.5 Vaults and Valve Chambers. These chambers should be watertight or self- draining.

8.4.4 Safety. Provide structural and operational safety.

8.4.4.1 Structural Safety

a) Vent. Adopt a size to relieve the air pressure caused by the change of water level. Maximum air velocity through the opening area should not exceed 1,000 fpm. Design the screen so that, if clogged by insects or frost, it will either swing on hinges or collapse before allowing damage to the tank.

b) Overflow. Provide a minimum capacity equal to the maximum inlet flow.

8.4.4.2 Operational Safety

a) Ladders. Provide ladders for standpipes and elevated tanks with a safety cage and safety line wherever possible.

b) Railings. Provide railings for all elevated tank balconies.

8.4.5 Protection Against Vandalism. Install a wire fence and locked gate around outdoor storage tanks, to prevent unauthorized intrusion.

Section 9: BUILDINGS

9.1 Building Design. Buildings in support of water supply system should be located and designed to provide adequate fire, explosion, natural hazard, chemical hazard and work hazard safety. Design should provide adequate operation and maintenance space; and proper instrumentation, lighting, heating and ventilation. Construction materials should be noncombustible and consider the toxic effects of chemicals. The comfort of operating personnel must be considered.

REFERENCES

NOTE: THE FOLLOWING REFERENCED DOCUMENTS FORM A PART OF THIS HANDBOOK TO THE EXTENT SPECIFIED HEREIN. USERS OF THIS HANDBOOK SHOULD REFER TO THE LATEST REVISIONS OF CITED DOCUMENTS UNLESS OTHERWISE DIRECTED.

FEDERAL/MILITARY STANDARDS, BULLETINS, INSTRUCTIONS, AND HANDBOOKS:

Military Handbooks, Design Manuals and Instructions. Government agencies and the private sector may obtain standardization documents from the DODSSP, Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.

The Construction Criteria Base (CCB) website is www.ccb.org

AF 132-1066	Plumbing Systems.
AFMAN 32-1071,	Security Engineering Manual
NAVFAC DM-7 Series	Soil and Foundations
MIL-HDBK 1002/02	Military Handbook Loads
MIL-HDBK 1003 Series	Mechanical Engineering
MIL-HDBK-1004/10	Cathodic Protection, Electrical Engineering
MIL-HDBK-1008C	Fire Protection for Facilities Engineering, Design, and Construction
MIL-HDBK 1025 Series	Piers and Dockside Facilities
MIL-HDBK 1029 Series	Drydocks and Marine Railways
NAVFACINST 11330.11D	Backflow Preventers, Reduced Pressure Principle Type
NAVMED P-5010-6	Manual of Naval Preventive Medicine Chapter 6
OPNAVINST 5510.45	U.S. Navy Physical Security Manual

U.S. Army TI-809-04 Seismic Design for Buildings (Tri-Service Manual)

OTHER GOVERNMENT DOCUMENTS AND PUBLICATIONS:

40 Code of Federal Regulations Part 141, U.S. EPA National Primary Drinking Water Regulations & Part 143, National Secondary Drinking Water Regulations.

Design of Small Dams, U.S. Department of the Interior, Bureau of Reclamation, Attn: D-7923A. P.O. Box 25007, Denver, CO 80225-0007.

USDA Soil Surveys

U.S. Environmental Protection Agency publications are available from U.S. Environmental Protection Agency, Office of Water Program Operations, Washington D.C.

EPA-430/99-74-001. Design Criteria for Mechanical, Electrical and Fluid System Component Reliability.

EPA-600/2-79-162a, Estimating Water Treatment Costs, Vol. 1, Summary, August 1979.

EPA-600/8-77-005, Manual of Treatment Techniques for Meeting the Interim Primary Drinking Water Regulations, May 1977.

USGS Topographical maps, stream flow data, and rainfall data

NON-GOVERNMENT STANDARDS AND OTHER PUBLICATIONS:

American Civil Engineering Practice, Vol. 2, Abbett, R. W., John Wiley & Sons, New York, NY 10016.

Groundwater & Wells, by Driscoll, published by Johnson Division, St. Paul Minnesota

Hydraulic Institute Standards, Hydraulic Institute, 712 Lakewood Center North, 9 Sylvian Way, Parsippany, NJ 07054-3802.

Hydraulic Transients, Rich, George R., McGraw-Hill Book Company, New York, NY, 1951.

Manual for Railway Engineering, American Railway Engineering Association (AREA), 50 F Street, N.W., Washington, D.C. 20001

Manuals of Cross-Connection Control, Foundation for Cross-Connection Control & Hydraulic Research, University of Southern California.

National Electrical Manufacturers Association Standards (NEMA)

NFPA publications are available from National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA Standard No. 20 Installation of Centrifugal Fire Pumps

NFPA Standard No. 22 Water Tanks for Private Fire Protection

Pumping Manual, T.C. Dickenson, Hydraulic Institute, 9 Sylvan Way, Parsippany, NJ 07054-3802

Recommended Standards for Water Works, 1997 Edition, Health Education Services, A Division of Health Research, Inc., P.O. Box 7126, Albany, N.Y. 1-518-439-7286

Standard Methods for Examination of Water and Wastewater, American Public Health Association, New York, NY 10019.

Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60062.

UL246 Hydrants for Fire Protection Service

UL262 Gate Valves for Fire Protection Service

Water and Wastewater Engineering, Fair, G. M., J. C. Geyer, and D. A. Okun, John Wiley & Sons, Inc., New York, NY 10016.

Water Rights in The Fifty States and Territories, by Kenneth Wright

Water Treatment Membrane Processes, American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235, 1996

Water Treatment Plant Design, American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235 Third or Latest Edition

Water Quality and Treatment, A Handbook of Public Water Supplies, American Water Works Association, Inc., McGraw Hill Book Company, New York, 4th or latest edition.

AWWA Manuals; American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado 80235.

M2 Automation and Instrumentation

M4 Water Fluoridation Principles and Practices

M6 Water Meters - Selection, Installation, Testing and Maintenance

M9 Concrete Pressure Pipe

M11 Steel Pipe - A Guide for Design and Installation

M12 Simplified Procedures for Water Examination

M14 Recommended Practice for Backflow Prevention and Cross-Connection Control

M17 Installation, Field Testing, and Maintenance of Fire Hydrants

M19 Emergency Planning for Water Quality Management

M20 Water Chlorination Principles and Practices

M21 Groundwater

M23 PVC Pipe - Design and Installation

M27 External Corrosion - Introduction to Chemistry and Control

M31 Distribution System Requirements for Fire Protection

M32 Distribution Network Analysis for Water Utilities

M38 Electro dialysis and Electro dialysis Reversal

M41 Ductile-Iron Pipe and Fittings

M44 Distribution Valves: Selection, Installation, Field Testing, and Maintenance

M45 Fiberglass Pipe Design

AWWA Standards; American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235.

A100	Water Wells
B501	Sodium Hydroxide (Caustic Soda) (Includes addendum B501a-97)
B502	Sodium Polyphosphate, Glassy (Sodium Hexametaphosphate) (Includes addendum B502a-97)
B503	Sodium Tripolyphosphate (Includes addendum B503a-97)
B504	Monosodium Phosphate, Anhydrous (Includes addendum B504a-97)
B505	Disodium Phosphate, Anhydrous (Includes addendum B505a-97)
B510	Carbon Dioxide (Includes addendum B510a-97
B511	Potassium Hydroxide
B512	Sulfur Dioxide
B550	Calcium Chloride (Includes addendum B550a=97)
B600	Powdered Activated Carbon
B601	Sodium Metabisulfite (Includes addendum B601a-97)
B602	Copper Sulfate (Includes addendum B602a-97)
B603	Potassium Permanganate (Includes addendum B603a-97
B604	Granular Activated Carbon
B701	Sodium Fluoride (Includes addendum B701a-97)
B702	Sodium Fluorosilicate (Includes addendum B702a-97)

B703	Fluorosilicic Acid (Includes addendum B703a-97)
C104	ANSI Standard for Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water
C110	ANSI Standard Ductile-Iron and Gray-Iron Fittings, 3 in. Through 48 in., for Water and Other Liquids
C111	ANSI Standard Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
C151	ANSI Standard for Ductile-Iron Pipe, Centrifugally Cast, for Water
C200	Steel Water Pipe-6 in. (150 mm) and larger
C205	Cement-Mortar Protective Lining and Coating for Steel Water Pipe - 4 in. and Larger - Shop Applied
C206	Field Welding of Steel Water Pipe
C207	Steel Pipe Flanges for Waterworks Service - Sizes 4 In. Through 144 In. (100 mm Through 3,600 mm) (Includes erratum C207-94)
C210	Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines
C219	Bolted, Sleeve-Type Couplings for Plain-End Pipe
C221	Fabricated Steel Mechanical Slip-Type Expansion Joints
C300	Reinforced Concrete Pressure Pipe, Steel-Cylinder Type
C301	Prestressed Concrete Pressure Pipe, Steel-Cylinder Type, for Water and Other Liquids
C302	Reinforced Concrete Pressure Pipe, Noncylinder Type
C303	Concrete Pressure Pipe, Bar-Wrapped, Steel-Cylinder Type
C304	Design of Prestressed Concrete Cylinder Pipe
C500	Metal-Seated Gate Valves for Water Supply Service
C501	Cast Iron Sluice Gates

C502	Dry-Barrel Fire Hydrants (Includes addendum C502a-95)
C504	Rubber-Seated Butterfly Valves
C507	Ball Valves, 6 in. Through 48 in.
C508	Swing-Check Valves for Waterworks Service, 2 in. Through 24 in. NPS (Includes addendum C508a-93)
C509	Resilient-Seated Gate Valves for Water Supply Service
C600	Installation of Ductile-Iron Water Mains and Their Appurtenances
C605	Underground installation of Polyvinyl Chloride (PVC) Pressure Pipe and Fittings for Water
C651	Disinfecting Water Mains
C654	Disinfection of Wells
C700	Cold-Water Meters - Displacement Type, Bronze Main Case
C800	Underground Service Line Valves and Fittings (Also included: Collected Standards for Service Line Materials)
C900	Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4 In. Through 12 In, for Water Distribution
C905	Polyvinyl Chloride (PVC) Water Transmission Pipe and Fabricated Fitting 14 in. Through 36 in., for Water Transmission
C906	Polyethylene (PE) Pressure Pipe and Fittings, 4 In. Through 63 In., for Water Distribution
C907	Polyvinyl Chloride (PVC) Pressure Fittings for Water - 4in. Through 8 in.
C950	Fiberglass Pressure Pipe
D100	Welded Steel Tanks for Water Storage
D102	Coating Steel Water Storage Tanks

D110	Wire and Strand-Wound, Circular, Prestressed Concrete Water Tanks (Includes addendum D110a-96)
D115	Circular Prestressed Concrete Water Tanks With Circumferential Tendons

GLOSSARY

APHA. American Public Health Association.

AREA. American Railway Engineering Association.

AWWA. American Water Works Association.

BHP. Brake horsepower.

BUMED. Bureau of Medicine and Surgery.

CT. Contact time.

EPA. Environmental Protection Agency.

FGS. Final Governing Standards.

NPSH. Net positive suction head.

OEBGD. Overseas environmental baseline guidance documents.

PE. Polyethylene.

POL. Petroleum oils and lubricants.

PVC. Polyvinyl chloride.

SCBA. Self-contained breathing apparatus.

TOC. Total organic carbon.

TTHM. Total trihalomethanes.

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